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ABSTRACT

This guide is intended for use in teaching an introductory course in manufacturing materials and processes. The course centers around four basic materials--metallics, polymers, ceramics, and composites--and seven manufacturing processes--casting, forming, molding, separating, conditioning, assembling, and finishing. Concepts and classifications of material conversion, fundamental manufacturing materials and processes, and the main types of manufacturing materials are discussed in the first section. A course content outline is provided in the second section. The remainder of the guide consists of learning modules on the following topics: manufacturing materials and processes, the nature of manufacturing materials, testing materials, casting and molding materials, forming materials, separating materials, conditioning processes, assembling processes, finishing processes, and methods of evaluating and analyzing products. Each module includes information about the length of time needed to complete the module, an introduction to the instructional content to be covered in class, performance objectives, a day-by-day outline of student learning activities, related diagrams and drawings, and lists of suggested textbooks and references. (MN)

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The North Carolina Technology Education Curriculum is the product of a curriculum redirection process begun in the early seventies. As in any change process, many individuals have contributed their time and energies to provide North Carolina students with a curriculum designed to meet their needs to be technologically literate adult citizens. The following are recognized for their vision and leadership in setting the direction for Technology Education in North Carolina schools.

Members of the N.C. Curriculum Study Taskforce who charted the course for technology education in North Carolina schools. Their study report and recommendations provided the direction for a change in the identity of the discipline and a total redirection of the curriculum.

Members of the N.C. Curriculum Committee who validated the Technology Education Curriculum Guide as appropriate study for assisting students in understanding technological systems impacting on their lives. Further, industry representatives of the committee verified the appropriateness of suggested activities reflective of practices in construction, communications, manufacturing, and transportation.

N.C. Technology Education Association who provided a forum for redirection of the discipline. It was the association that led the profession in changing identity to technology education. The association also provided opportunities for professionals to develop competence in the classroom delivery of technology education through the sponsorship of in-service programs.

Individual technology education professionals who gave leadership to other professionals in the curriculum change process. These professional leaders piloted many technology education activities in their classrooms and served as role models for other professionals.

Members of the N.C. Council of Technology Teacher Educators who provided insite and support throughout the curriculum redirection process.

Indiana curriculum developers who provided curriculum materials adopted and adapted for North Carolina Technology Education programs.

INTRODUCTION

The North Carolina Technology Education Curriculum is a program to meet every citizen's need to be technologically literate. Some basic assumptions underlie the program, and these can be divided into content assumptions, and learner assumptions.

The curriculum was developed using the belief that the appropriate content for the field is technology, and its impact on individuals and society. It was further assumed that the content is best organized around human productive systems that have been used, are now being used, and will, most likely, continue to be used. These universal systems are communication, construction, manufacturing, and transportation. Finally, it was assumed that this content can best be addressed from a systems approach with its inputs, processes, outputs, feedback, and goals/restraints.

The curriculum was further based on the assumption that education should meet the needs of individuals and the human requirements of society. It was assumed that each person living in a technological society should have a basic understanding of and the ability to assimilate the knowledge about technology. People it was assumed, should be able to interact with the technological nature of society and help impact the type of future new technologies can provide. Additionally people should be able to be contributors to a society in their several roles, including citizen, voter, investor, consumer, worker, and leader.

These assumptions caused the curriculum to be developed in such a way as to:

1. Provide an overview of technology first, allow for more indepth study in specific technological areas, and culminate with synthesis activities.

2. Be more teacher-directed, content-centered in early courses, and highly, student-directed, process centered in advanced courses.

3. Involve problem-solving and group activities of all courses.

4. Stress the how and why of technology and its relationship to our quality of life.

5. Be activity-centered learning, with the content being used to determine the appropriateness of each activity selected.

6. Be equally important to young women and young men, both of which must function in a technological society.

Finally, the curriculum was developed to be descriptive rather than prescriptive. The materials describe what to teach and suggest ways of teaching the content. At no time are daily activities prescribed in such a way to preclude individualizing the presentations to meet local conditions.

THE CURRICULUM GUIDE IN AN INSTRUCTIONAL SYSTEM

Each course in the North Carolina Technology Education Curriculum is seen as a dynamic activity involving a complete instruction system. This system generally includes seven components: the teacher, the students, a texbook when available, the curriculum guide, laboratory sheets, apparatus, and a reference library.

THE TEACHER

The teacher plays the primary role in the system. This role entails being a curriculum developer. The teacher chooses the points to emphasize and to evaluate. Care should be taken to insure that the coverage of the subject is comprehensive. You should resist "picking and choosing" only modules and activities that are the most interesting, most familiar, or the easiest to implement. All modules and activities should be included. However, you are encouraged to redesign or replace activities with your own activities that contain equivalent content.

As a technical expert, the teacher gives presentations, demonstrations, and asks questions about the subject matter. Safety information, and the demonstration of teaching/learining activities, are the responsibility of the teacher.

The teacher is an instruction manager. Managers plan, schedule, direct, and control activities. The teacher, perhaps in cooperation with students, plan the instruction by identifying the instructional goals. The activities to reach these goals are scheduled. Through presentations and application activities students are directed through the construction activities. Finally, the student's work and the teacher's management is controlled through various forms of evaluation. Since evaluation instruments should be designed to measure success in reaching the goals, these instruments should be prepared by the teacher.

The teacher is the creator of the teaching/learning environment. It is highly recommended that you create a "role playing" environment. In addition to having students do tasks that simulate construction, have them play the role of workers, managers, and owners. For example, refer to a group of students as a "work crew" or "survey party" with job titles, rather than as students who carry out assigned tasks. Help them visualize themselves in their roles. The teacher can become a job superintendent, owner, or government officer, who approves the "work crew's" job.

THE STUDENT

The target population is made up of middle-junior high or high school students. The students will often work in groups of from three to five. Their responsibilities include reading the textbook assignments, doing the worksheets as homework, and completing the activities.

THE TEXBOOK

A textbook should be selected for the course and each student should have one. A textbook contains the body of knowledge about industrial technology. It should be selected to meet the appropriate reading level, and be written in an interesting way with numerous illustrations.

THE CURRICULUM GUIDE

The curriculum guide is to be used to help plan your instruction. The introduction consists of a structure for the content and a description of an instructional system with suggestions on how to use it.

The remainder of the curriculum guide briefly describes the modules. Each module consists of an introduction, objective(s), and a description of the activities. The description of the activities includes a schedule, presentation titles, application activities, and presentation titles, references, and safety guidelines. Suggestions for getting prepared and carrying out the activity are found in the teacher activity sections.

Suggestions for a variety of optional activities may also be found throughout the curriculum guide.

THE APPARATUS

Often the course guide contains plans for specialized apparatus useful in teaching the course. Drawings will be placed with the activity in which they are used. You can use the drawings to construct the apparatus.

THE REFERENCE LIBRARY

Some courses require student reference books. The titles of these are included in the reference library and copies should be purchased for laboratory use.

DAILY LESSON PLANS AND EVALUATION

The planning of daily activities and an on going evaluation system are th teacher's responsibility and rightfully so. Each student should adapt activities and presentations to insure they help students develop the identified concepts within local conditions. The curriculum guide was designed to help you, the local professional, present a relevant, exciting course. Good luck!

INTRODUCTION TO MANUFACTURING MATERIALS AND PROCESSES

This course is designed to provide an understanding of manufacturing materials and processes. Its primary concerns are the characteristics and properties of industrial materials and the processing (conversion) of industrial materials into consumer and industrial goods. A process can be defined as the conversion or transmission of materials, energy, or information; or the transporting of materials, humans, and/or machines from one physical location to another. Materials are commonly referred to as any matter in the form of solid, liquid, or gas. However, this introductory course is primarily concerned with the investigation and evaluation of four solid engineering materials: (1) metallics, (2) polymers, (3) ceramics, and (4) composites.

A large number and wide variety of material conversion processes and materials are used to produce the consumer goods and industrial products of modern industry. These materials and processes might include: steel, aluminum, copper, pine, rubber, polystyrene, glass, cement, drilling, reaming, sawing, milling, printing, curing, stapling, bending, pouring, etc. But, this unending list of materials and processes presents a problem when trying to study and understand manufacturing materials and processes. Which materials and processes should be studied? Also, how can students prepare to understand and comprehend new and future industrial materials and processes.

The study of individual, isolated materials and processes is sometimes difficult and unsatisfactory. The study tends to emphasize the differences among individual material conversion processes and materials; and fails to examine the many similarities that exist between them. By placing the emphasis on the learning of facts and isolated skills, the task is endless, many times nontransferable, and less than satisfactory.

A more promising method for the study of manufacturing materials and processes is in the study of the concepts, principles, characteristics, and classifications of industrial materials and processes.

CONCEPTS AND CLASSIFICATIONS OF MATERIAL CONVERSION

To aid in the investigation of secondary operations (material conversion), a conceptual model of material conversion is used to analyze and describe processes used to convert raw materials into finished products. The concept identifies and describes four (4) different material conversions or changes:

1. separation of materials
2. addition of materials
3. contour change of materials
4. internal change of materials

After gaining a working knowledge of the material conversion concept, students should be able to use the concept to support the development of understanding of current material conversion processes, and as a tool to guide future learning.

A classification system is also used to improve the learner's understanding of industrial manufacturing processes. Through the use of this classification system it is possible to group hundreds of manufacturing processes into seven (7) industrial classifications. These classifications are as follows:

1. **Casting**—material conversion processes whereby material is liquified and then introduced into a mold cavity. After solidification the casting is extracted.
2. **Forming**—processes change a material's size or shape, but not volume. Material conversion takes place by the application of force between the materials yield and fracture points.
3. **Molding**—material conversion processes which change the size or shape of a material by applying force to a pliable, semi-solid, granular, or powdered material.
4. **Separating**—material conversion processes which remove material for the purpose of changing its size, shape, volume, and/or surface finish.
5. **Conditioning**—material conversion processes used to change a material's characteristics or properties by applying thermal, mechanical, chemical, and/or electromagnetic energy to the material being converted.
6. **Assembly**—material conversion processes used to semi- or permanently join two or more materials or parts together.
7. **Finishing**—material conversion processes used to improve, protect, decorate, and/or change the properties of a material's surface.

In this course each of the above classifications is a major body of content. It is through the study of the common principles of each and the performance of related laboratory activities, that understanding is developed and reinforced.

MANUFACTURING MATERIALS

Solid materials commonly referred to as engineering materials can be grouped into four material families: (1) polymeric, (2) metallic, (3) ceramic, and (4) composite. Each of these materials has certain properties and characteristics that are dependent upon the material's chemical and physical structure. Polymer materials are often subdivided into two subgroups: (1) natural (wood) and (2) synthetic (plastics). Metallics are traditionally grouped into ferrous and nonferrous. Stone, cement, glass, clay, oxides, and carbides, are all types of ceramic materials. Composite materials can be grouped according to their physical structure: fiber, particle, laminate, flake, and filler. In this course, the nature, composition, properties, and characteristics of materials will be discussed and investigated through the use of destructive and non-destructive techniques.

COURSE CONTENT

The content of Manufacturing Materials and Processes is centered around manufacturing input, primary and secondary processes, the concept of material conversion, families of industrial materials, and classifications of manufacturing processes. Care should be taken to ensure that each concept, principle, or understanding, is thoroughly understood before proceeding to the next, because of the necessity to build a strong knowledge base in each area. Each topic should be introduced to students using a broad array of examples, placing major emphasis on the concepts and principles under discussion, rather than the individual processes or materials that are used as examples, and to reinforce the content.

COURSE DESCRIPTION AND OBJECTIVES FOR MANUFACTURING MATERIALS AND PROCESSES

This course provides students with an introduction to (1) the properties of materials—metallic polymeric, ceramic, and composite, and (2) the manufacturing processes--casting, forming, separating, conditioning, assembling, and finishing used to convert these materials into industrial and consumer products.

MANUFACTURING MATERIALS AND PROCESSES

Experiences and activities of this course will enable the student to:

1. Develop an understanding of the role and function of manufacturing materials and processes in industry and technology.
2. Develop conceptual frameworks that aid the understanding, application, and transfer of current and future manufacturing materials and processes.
3. Develop and reinforce the understanding of the properties and characteristics of manufacturing materials and processes through participation in "hands-on" laboratory-centered learning experiences.
4. Develop a knowledge based on which social and environmental decisions can be made regarding the importance and selection of manufacturing materials and processes used in the development and production of industrial and consumer goods.
5. Apply problem-solving and organizational skills to the investigation of industrial materials and processes.

COURSE OUTLINE

Module Number	Title and Content	Time (Days)
1	Manufacturing Materials and Processes Manufacturing input and output Types of processes Manufacturing materials	8
2	Nature of Manufacturing Materials Types of materials Properties of materials	7
3	Testing Materials Types of material tests Testing procedures Conducting tests and reporting results	15
4	Casting and Molding Materials Principles of casting and molding Performing and evaluating casting and molding processes	9
5	Forming Materials Principles of forming Performing and evaluating forming processes	9
6	Separating Materials Principles of separating Performing and evaluating separating processes	13
7	Conditioning Processes Principles of conditioning Performing and evaluating conditioning processes	4
8	Assembling Processes Principles of conditioning Performing and evaluating assembling processes	7
9	Finishing Processes Principles of finishing Performing and evaluating finishing processes	5
10	Evaluating and Analyzing Products	4

COURSE CONTENT

I. Introduction to Manufacturing Processes and Materials
  A. Managing
  B. Systems and concepts of manufacturing processes and materials
  C. Material conversion processes
  D. Material characteristics and properties

II. Manufacturing Inputs
  A. Material
    1. Types
    2. Systems
    3. Properties
    4. Service requirements
    5. Source
      a. Direct
      b. Indirect
  B. Energy (types and sources)
    1. Mechanical
    2. Thermal
    3. Electrical
    4. Radiant
    5. Nuclear
    6. Sources (solar, food/fuel, wind, water, geothermal, nuclear, chemical potential)
  C. Information
    1. Elements of information
      a. Signals
      b. Symbols
      c. Codes
      d. Noise
      e. Entropy
    2. Signals
      a. Analog (continuous)
      b. Digital (discrete)
      c. Mixed
    3. Symbols (sematic, symbolic, figural)
    4. Codes (meaning, efficiency, redundancy)
    5. Information conversion and control
      a. Generating
      b. Transmitting
      c. Transducing
      d. Sensing
      e. Receiving
      f. Media
      g. Noise
      h. Feedback

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6. Information sampling
    a. Sensors
    b. Transducers
7. Information in production (process, handling, control, cybernation, and feedback)
8. Communication participants
    a. Human to human
    b. Human to machine
    c. Machine to machine
    d. Machine to human
9. Knowledge
    a. Technical
    b. Scientific
    c. Humanities
    d. Formal

D. Machines
1. Tools, machines, and mechanisms
2. Types of machines
    a. Energy conversion
    b. Material conversion
    c. Information conversion
3. Machine inputs and outputs
    a. Energy
    b. Information
    c. materials
4. Machine functions (processes performed by)
    a. Transmit
    b. Transport
    c. Convert
5. Machine systems
    a. Support and cover
    b. Energy transmission
    c. Guidance and control
6. As converters
    a. Mechanical—physical, pneumatic, hydraulic, sonic
    b. Other—chemical, thermal, electric, magnetic, radiant, nuclear

E. Processes (material conversion)
1. Contour changes
2. Separation changes
3. Addition changes
4. Internal changes

- F. Human
  - 1. Social influences
  - 2. Psychological influences
  - 3. Biomechanical influences
  - 4. Systems
    - a. Managerial
    - b. Scientific/technical
    - c. Office/clerical
    - d. Worker/operative
- G. Finance
  - 1. Debt
  - 2. Equity
- H. Capital
  - 1. Plant
  - 2. Equipment

III. Manufacturing Outputs

- A. Raw materials
  - 1. State
    - a. Liquid
    - b. Gas
    - c. Solid
  - 2. Properties
    - a. Mechanical
    - b. Physical
    - c. Chemical
    - d. Thermal
    - e. Electrical and magnetic
    - f. Optical
    - g. Acoustical
    - h. Physicochemical
- B. Industrial manufacturing goods
  - 1. Types
    - a. Polymeric
    - b. Metallic
    - c. Ceramic
    - d. Composite
  - 2. Systems
    - a. Monolithic (basic and natural)
    - b. Material systems
    - c. Dynamic materials
  - 3. Properties
    - a. Mechanical
    - b. Physical
    - c. Chemical
    - d. Thermal
    - e. Electrical and magnetic

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        - f. Optical
        - g. Acoustical
        - h. Physicochemical
    - C. Finished goods
        - 1. Classes
            - a. Consumer
            - b. Industrial
            - c. Military
        - 2. User selection criteria
            - a. Appearance
            - b. Function
            - c. Economic value
            - d. Status value
            - e. Environmental impact
            - f. Service requirements
    - D. Other outputs
        - 1. Scrap
            - a. Recyclable
            - b. Waste
                - (1) Hazardous
                - (2) Nonhazardous
        - 2. Pollution
            - a. Air
            - b. Water
            - c. Land/soil
            - d. Ecocycle
            - e. Noise

- IV. Primary Processes (Extracting)
    - A. Drilling
        - 1. Methods
            - a. Cable tool
            - b. Rotary
        - 2. Extracting materials
            - a. Energy drive
            - b. Pumping
    - B. Harvesting
        - 1. Selective cutting
        - 2. Clear cutting
        - 3. Picking
        - 4. Filtering
        - 5. Other

- C. Mining
    - 1. Placer (panning)
    - 2. Dredging
        - a. Floating
        - b. Drag line
    - 3. Open pit
    - 4. Strip
    - 5. Quarry
    - 6. Underground
        - a. Level and shaft
        - b. Room and pillar
        - c. Precipitating
        - d. Leaching
        - e. Frasch
        - f. Drag line
    - 7. Other
        - a. Evaporation
        - b. Electrolysis
- D. Concentrating—through separation of undesirable materials

V. Primary Processing (Other)

- A. Thermal processing
    - 1. Smelting
    - 2. Distilling
    - 3. Evaporating
- B. Chemical processing
    - 1. Oxidizing
    - 2. Reducing
- C. Mechanical processing
    - 1. Slicing and shearing
    - 2. Crushing and milling
    - 3. Cutting
    - 4. Screening
    - 5. Floating and sedimenting
    - 6. Filtering
- D. Electrical processing
    - 1. Magnetic separating
    - 2. Electrostatic separating

VI. Concepts of Material Conversion

- A. Separation changes
    - 1. Separation with a wedge
        - a. With a chip—machining
        - b. Without a chip—shearing
    - 2. Separation without a wedge
        - a. With a chip
        - b. Without a chip
    - 3. Separation with and without force

- B. Contour changes
    - 1. Preparation of material
    - 2. Contouring device
    - 3. Introduction of the material into the contouring device
    - 4. Contouring force
    - 5. Material deformation and/or solidification
    - 6. Removal of the material from the device
- C. Addition changes
    - 1. Mixing
    - 2. Adhesion
    - 3. Cohesion
    - 4. Mechanical linkage
    - 5. Weaving/interlacing
    - 6. Magnetic
    - 7. Co-cure
- D. Internal changes
    - 1. Material characteristics
    - 2. Desired material characteristics
    - 3. Conversion processes
        - a. Thermal
        - b. Mechanical
        - c. Magnetic
        - d. Chemical
        - e. Optical
        - f. Acoustic
        - g. Electrical
    - 4. Characteristics obtained (properties)
        - a. Mechanical
        - b. Physical
        - c. Chemical
        - d. Thermal
        - e. Electrical and magnetic
        - f. Optical
        - g. Acoustical
        - h. Physicochemical

VII. Industrial Classification of Manufacturing Processes

- A. Casting principles
    - 1. Preparation of the material
        - a. Heat
        - b. Dissolve
        - c. Mix
    - 2. Prepare cavity (mold)
        - a. Permanent
        - b. Expendable

  3. Introduce material
    a. Gravity
    b. Pressure
  4. Solidify material
    a. Cooling
    b. Chemical reaction
    c. Other
  5. Extract material
    a. Destroy
    b. Open
B. Molding techniques include
  1. Injection molding
  2. Blow molding
  3. Extruding
  4. Compression molding
  5. Rotational molding
  6. Cold molding
C. Forming principles
  1. Material
    a. Hot
    b. Cold
    c. Other
  2. Shaping device
    a. Open die
    b. Closed die
    c. Mated die
    d. One piece
    e. Roll
  3. Contouring force
D. Separation principles
  1. Types
    a. Shearing
    b. Machining
    c. Nontraditional
  2. Cutting tools
    a. Single point
    b. Multiple point
  3. Tool or material motion
    a. Linear
    b. Reciprocating
    c. Rotary
    d. Stationary
  4. Coolant
  5. Material and cutting tool support

- E. Conditioning principles
    - 1. Characteristics or properties desired
        - a. Mechanical
        - b. Physical
        - c. Chemical
        - d. Thermal
        - e. Optical
        - f. Acoustical
        - g. Physicochemical
        - h. Processing
        - i. Environmental
    - 2. Structure to be converted
        - a. Atomic (bonding)
        - b. Crystal
        - c. Molecular
        - d. Micro-macro
    - 3. Conversion processes
        - a. Thermal
        - b. Mechanical
        - c. Chemical
        - d. Acoustical
        - e. Optical
        - f. Electrical
    - 4. Characteristics or properties obtained
        - a. Mechanical
        - b. Physical
        - c. Chemical
        - d. Thermal
        - e. Optical
        - f. Acoustical
        - g. Physicochemical
        - h. Processing
        - i. Environmental
- F. Assembling techniques
    - 1. Mixing
    - 2. Joining
        - a. Adhesion
        - b. Cohesion
        - c. Mechanical
    - 3. Weaving
    - 4. Magnetic
- G. Finishing principles
    - 1. Select finish
        - a. Coating
        - b. Conversion

  2. Prepare material for finishing
     a. Mechanical
     b. Chemical
  3. Apply finish
     a. Spraying
     b. Dipping
     c. Plating
     d. Rolling
     e. Brushing
     f. Pouring

VIII. Manufacturing Materials
  A. State
    1. Solid
    2. Liquid
    3. Gas
  B. Types (engineering materials)
    1. Polymeric
      a. Natural (wood)
        (1) Structure of wood
        (2) Properties of wood
          (a) Moisture
          (b) Specific gravity
          (c) Physical properties
          (d) Mechanical properties
          (e) Other properties
      b. Synthetic (plastic)
        (1) Structure of plastic
          (a) Thermoset
          (b) Thermoplastic
          (c) Elastomers
          (d) Types of polymer chains
            [1] Linear polymer chains
            [2] Branched polymer chains
            [3] Cross-linked polymer chains
        (2) Properties of plastics
    2. Metallic
      a. Ferrous and nonferrous
      b. Metallic structure
      c. Metallic properties
    3. Ceramic
      a. Raw materials and structures
      b. Ceramic properties

      - c. Types
        - (1) Stone
        - (2) Cement
        - (3) Glass
        - (4) Clay
        - (5) Oxides
        - (6) Carbides
    - 4. Composite
      - a. Structure of
        - (1) Fiber
        - (2) Particle
        - (3) Laminate
        - (4) Flake
        - (5) Filler
- C. Nature of materials
  - 1. Atomic theory
  - 2. Bonding
    - a. Covalent
    - b. Ionic
    - c. Metallic
    - d. Van der Walls forces
  - 3. Crystal structure
  - 4. Macro- and microscopic structure
- D. Material systems
  - 1. Monolithic materials
    - a. Natural
    - b. Basic
  - 2. Systems
    - a. Composites
    - b. Diffusion
    - c. Fiber reinforcing
    - d. Alloying
    - e. Powder compacting
    - f. Sandwiches
    - g. Cladding
    - h. Bonding
    - i. Coating
    - j. Laminating
  - 3. Dynamic materials
    - a. Expanding
    - b. Metamorphic
    - c. Functional
- E. Material characteristics and properties
  - 1. Mechanical (static and dynamic)
    - a. Tension
    - b. Compression
    - c. Shear
    - d. Stiffness

   e. Elasticity
   f. Plasticity
   g. Ductility
   h. Brittleness
   i. Hardness
   j. Creep
   k. Fatigue
   l. Torsion
   m. Flexure
   n. Endurance
2. Physical
   a. Dimensions
   b. Density or specific gravity
   c. Porosity
   d. Moisture content
   e. Macrostructure
   f. Microstructure
   g. Permeability
   h. Weight
   i. Volume
   j. Surface texture
   k. Absorption
   l. Color
3. Thermal
   a. Specific heat
   b. Thermo expansion
   c. Thermo conductivity
   d. Thermo electric
4. Chemical (properties of composition and structure effect)
   a. Acidity or alkalinity
   b. Corrosion
   c. Toxidity
   d. Oxidation
   e. Environmental attack
   f. Electrochemical corrosion
   g. Water absorption
   h. Reactivity
5. Electromagnetic
   a. Conductivity
   b. Magnetic permeability
   c. Di-electric properties
   d. Galvanic action
   e. Wave transmission

6. Optical
    a. Color
    b. Light transmission
    c. Reflection
    d. Absorbent
    e. Transparency
    f. Refractivity
    g. Luminescence
        (1) Fluorescence
        (2) Phosphorescence
    h. Photoelectric
    i. Photoelasticity
7. Acoustical
    a. Transmission
    b. Reflection
    c. Absorption
8. Physicochemical
    a. Water absorption
    b. Water repellent action
    c. Shrinkage and swelling due to changes in moisture content
9. Processing
    a. Machineability
    b. Formability
    c. Weldability
    d. Castability
    e. Drawability
    f. Finishability
    g. Joinability
    h. Toolability
    i. Fuseability
    j. Forgeability
10. Environmental
    a. Abrasive
    b. Chemical
    c. Temperature
    d. Weathering
    e. Insects

F. Service requirements
    1. Integrity of shape
    2. Strength
    3. Integrity of structure
    4. Service life
    5. Special functions
    6. Formability
    7. Cost
    8. Environmental effects

- G. Material testing
  - 1. Destructive
    - a. Tensile
      - (1) Stress/strain curve
      - (2) Proportional limit
      - (3) Yield point
      - (4) Ultimate strength
      - (5) Breaking strength
      - (6) Other
    - b. Compression
      - (1) Compression strength
      - (2) Length to diameter ratio
    - c. Flexure
      - (1) Flexure strength
      - (2) Types of tests
    - d. Impact
    - e. Fatigue
    - f. Creep
    - g. Torsion
    - h. Shear
    - i. Other
  - 2. Nondestructive
    - a. Visual
    - b. Radiographic
    - c. Magnetic
    - d. Electrical
    - e. Ultrasonic
    - f. Acoustic
    - g. Liquid penetrant
    - h. Eddy current
    - i. Other
  - 3. Common testing apparatus
    - a. Universal testing machine
      - (1) Tensile
      - (2) Compression
      - (3) Flexure
      - (4) Shear
      - (5) Other
    - b. Impact tester
      - (1) Izod
      - (2) Charpy

    c. Fatigue tester
    d. Creep tester
    e. Hardness tester
        (1) Brinell
        (2) Rockwell
        (3) Vickers
        (4) Scratch
        (5) Moh
    f. Radiographic tester
    g. Ultrasonic tester
    h. Eddy current tester
    i. Acoustic tester
    j. Liquid penetrant tester
    k. Magnetic flux tester
    l. Other
4. Test variables
    a. Loading methods
        (1) Static
        (2) Dynamic
    b. Temperature
    c. Accuracy
    d. Procedure
5. Stress/strain

BIBLIOGRAPHY

TEXTS AND REFERENCE BOOKS USED IN THE DEVELOPMENT OF MANUFACTURING MATERIALS AND PROCESSES

Suggested Textbooks

Kazanas, H. C., G. Baker, and Gregor, *Basic Manufacturing Processes*, McGraw-Hill Book Co., New York, 1981.

Wright, R. Thomas, *Processes of Manufacturing*, Goodheart-Willcox Co., South Holland, IL, 1987.

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Kazanas, H., R. Klein, and J. Lindbeck, *Technology of Industrial Materials*, Bennett Publishing Co., Peoria, IL, 1974.

Todd, R., D. McCrory, and Todd, *Understanding and Using Technology*, Davis Publishers, Worcester, MA, 1985.

MODULE: 1 : Manufacturing Materials and Processes

LENGTH: 8 DAYS Manufacturing CLUSTER

This module is designed to provide an introduction to manufacturing materials and processes. Its primary concerns are the characteristics and properties of industrial materials and the processing (conversion) of industrial materials into consumer and industrial goods. A process can be defined as the conversion or transmission of materials, energy, or information; or the transporting of materials, humans, and/or machines from one physical location to another. Materials are commonly referred to as any matter in the form of solid, liquid, or gas. However, in this module you will be primarily be concerned with the investigation and evaluation of four solid engineering materials: (1) metallics, (2) polymers, (3) ceramics, and (4) composites.

Manufacturing processes fall into two general categories: (1) primary operations, and (2) secondary operations. Primary operations are those processes which remove a material from its natural state and/or process into raw or basic materials. Examples of primary operations include: reduction of iron ore into iron, sea water into magnesium, timber into lumber, and synthetic chemicals into plastics. Such operations supply the raw or basic materials used in the manufacturing of industrial and consumer goods.

Secondary operations are those material conversion processes applied to basic materials. Examples include: milling, case hardening, drop forging, investment casting, sawing, riveting, etc. (Note: In a less formal sense, some engineers consider initial cutting or forming processes to be primary operations, and those processes that follow, as secondary. As an example, drilling a hole might be considered a primary operation, while the reaming or tapping of this hole would be a secondary one.) The introduction and study of secondary operations and basic engineering materials will be the focus of this module.

CONCEPTS OF MATERIAL CONVERSION

To aid in the investigation of secondary operations (material conversion), a conceptual model of material conversion will be used to analyze and describe the potential conversion processes that can take place when converting a material, from its raw state, to a finished product. This conceptual model of material conversion identifies and describes four different material conversions or changes:

1. separation of materials
2. addition of materials
3. contour change of materials
4. internal change of materials.

Separation of Materials

Separation processes change a material by removing material from the base or parent material for the purpose of changing the size, shape, volume, and/or surface finish of the base or parent material. There are three different types of separation processes. They are:

1. wedge/no chip (shearing)—the removal of material by a wedge cutting action with no loss of material (example—shearing)
2. wedge/chip (machining)—the removal of material by a wedge resulting in the generation of a chip (example—drilling...chip having no immediate value)
3. non-traditional—the removal of material without using conventional machining (wedge) machining forces (example—flame cutting).

Addition of Materials

Addition processes result in the semi-permanently and/or permanently joining together of two or more materials. Addition processes typically can be grouped under the following categories: adhesion, cohesion, co-cured, interlacing, mechanical, mixing, and magnetic.

Contour Change of Materials

Contour processes change the shape, but not the volume of a material. There are three general types of industrial contour processes—casting, forming, and molding.

Internal Change of Materials

Internal processes result in a change in the material's molecular or chemical structure. These changes in the material's chemical or molecular structure affects and/or determines the material's characteristics and properties. There are four general types of internal material conversion processes: (1) thermal, (2) chemical, (3) electromagnetic, and (4) mechanical. These changes are usually used to improve the material's performance and/or conversion characteristics.

INDUSTRIAL CLASSIFICATIONS OF MATERIAL CONVERSION

In order to improve the understanding and teaching of manufacturing processes, it is possible to group hundreds of manufacturing processes under seven industrial classifications. Each classification will be introduced and expanded upon in this module. These classifications are as follows:

1. Casting—material conversion processes whereby material is liquified and then introduced into a mold cavity. After solidification the casting is extracted.
2. Forming—processes change a material's size or shape, but not volume. Material conversion takes place by the application of force between the material's yield and fracture points.
3. Molding—material conversion processes which change the size or shape of a material by applying force to a pliable, semisolid, granular, or powdered material.
4. Separating—material conversion processes which remove material for the purpose of changing its size, shape, volume, and/or surface finish.
5. Conditioning—material conversion processes used to change a material's characteristics or properties by applying thermal, mechanical, chemical, and/or electromagnetic energy to the material being converted.
6. Assembly—material conversion processes used to semi- or permanently join two or more materials or parts together.
7. Finishing—material conversion processes used to improve, protect, decorate, and/or change the properties of a material's surface.

MATERIAL CHARACTERISTICS

Solid materials commonly referred to as engineering materials can be grouped into four classifications: (1) polymeric, (2) metallic, (3) ceramic, and (4) composite. Each of these materials has certain properties and characteristics that are dependent upon the material's chemical and physical structure. Polymer materials are often subdivided into two subgroups: (1) natural (wood), and (2) synthetic (plastics). Metallics are traditionally grouped into ferrous and nonferrous. Stone, cement, glass, clay, oxides, and carbides are all types of ceramic materials. Composite materials can be grouped according to their physical structure: fiber, particle, laminate, flake, and filler.

When introducing engineering materials topics such as atomic theory, bonding and structure should be discussed. Destructive and nondestructive tests can be used to demonstrate material properties and characteristics such as: mechanical, physical, thermal, chemical, electromagnetic, optical, acoustical, physicochemical, processing, service, and environmental.

The content of this module should be centered around primary and secondary processes, concepts of material conversion, families of industrial materials, manufacturing inputs, and seven classifications of manufacturing processes. Care should be taken to ensure that each concept, principle, or understanding is understood before proceeding to the next because of the necessity to build a strong knowledge base or foundation in each area. Introduce the student to each topic using a broad array of examples. Principle emphasis should be placed on the concepts and principles under discussion, rather than the individual processes or materials that are used as examples, and to reinforce the content.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe a process.
2. Identify four different engineering materials.
3. Define and give examples of primary and secondary operations.
4. Identify selected manufacturing material conversion processes and describe the conceptual processes used in each identified process.
5. Define and describe the seven classifications of manufacturing processes.
6. Identify and describe the four basic types of engineering materials and their subgroups.
7. Identify and describe selected material characteristics or properties and potential methods used to evaluate or measure them.
8. Discuss the impacts resulting from the extraction, processing, and utilization of manufacturing materials and processes on the environment and society.
9. Be aware of the relationship(s) among product function, material selection, and material processing.
10. Compare and describe selected material conversion processes.
11. Identify and describe the interrelationship of the manufacturing input of materials, energy, information, machines, processes, humans, finance, and capital.

CALENDAR

DAY	ACTIVITY
1	Introduction to manufacturing materials and processes. 1. class orientation 2. description of manufacturing inputs, systems, and outputs
2	Introduction to and discussion of manufacturing processes and material families. 1. industrial classifications of manufacturing processes 2. engineering materials 3. demonstration of material properties and characteristics through egg drop container activity
3	In-class time to design, engineer, and fabricate egg drop container.
4	Conduct egg drop container activity. Discussion of material properties that are favorable and unfavorable to design of the container.
5	Introduction to and discussion of the concepts of material conversion. 1. addition of materials 2. contour changes 3. separation of materials 4. internal changes.
6	Introduction to and discussion of the industrial classifications of manufacturing processes. Casting, molding, separating, conditioning, assembling, forming, and finishing.
7-8	Introduction to and discussion of "concept frame activity." Development of concept frames.

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module, select and/or develop the media and materials necessary to support your instruction.

Develop an assignment sheet with a description and specific instructions for the "concept frame activity."

Obtain the necessary supplies and materials that will assist the students in completing their assignments.

Identify, develop, and/or test equipment and procedures that will be used to demonstrate properties and characteristics.

1 Complete administrative duties required to start a class.

Introduce the Manufacturing Materials and Processes Course by briefly discussing and describing:

1. manufacturing inputs, systems, and output
2. primary and secondary processes
3. manufacturing processes
4. manufacturing materials.

Orient the students to the rules and regulations of the school and department.

Discuss subjects such as: attendance requirements, safety procedures, methods of evaluation, course objectives and goals, proposed course activities and experiences, etc.

2 Introduce and discuss manufacturing processes and manufacturing materials. Identify, describe, and give examples of the basic types of manufacturing processes:

1. casting and molding
2. separating
3. forming
4. conditioning
5. assembling
6. finishing.

Identify, describe, and give examples of the basic forms of industrial engineering materials:

1. metallics
2. polymers
3. ceramics
4. composites.

DAY **ACTIVITY**

Show the students a container that you have previously prepared that contains a raw egg. At this time, do not tell them it contains a raw egg. Take that container out into the laboratory and drop it from a given height. Briefly talk about the material properties, characteristics, and construction of the container and/or materials from which it is fabricated or filled with. Open the container without showing the students the internal construction of the container and show the students that it had contained an egg. Remove the egg and demonstrate, by breaking it, that the egg was indeed raw.

Give the students a previously prepared handout describing the criteria and rules for an egg drop contest which you have developed to match your facility and available resources of the students. Suggested criteria might include:

1. maximum cost
2. maximum weight
3. size
4. who furnishes the egg.

Also, establish a set of rules for determining the winner of the egg drop contest.

3 Allow the students two nights and one class period to design and construct their egg drop container. As students are designing and fabricating their containers, discuss with them the characteristics and properties of different materials that might be suitable and unsuitable for such a container.

4 Have each student bring in his/her egg drop container and egg (have an extra supply of eggs on hand just in case). Proceed with the contest. For those containers that exceed the maximum height available in your laboratory, move to a location that will allow for longer drops.

During the contest students should discuss the material properties, characteristics, and container designs used by the students in class.

DAY	ACTIVITY
5	Discuss manufacturing processes by introducing and describing the concepts of material conversion.

The discussion should focus on the contour, separation, addition, and internal changes that a part and/or product must go through as it progresses from a raw material to a finished product. Several examples of each conversion process should be used during the discussion. Potential examples include:

1. Using paper clips on the overhead projector and projecting changes on the screen:
    a. bend one paper clip (contour change)
    b. continue to bend until it breaks (separation change)
    c. bending causes work hardening (internal change)
    d. link two paper clips together (addition change).

2. Using two pieces of paper:
    a. fold lightly (contour change)
    b. fold and crease (contour change--permanent deformation)
    c. crease also causes internal change
    d. tear or cut with scissors (separation change--no chip)
    e. put two pieces together by folding corners (addition change).

3. Using clay, playdough, or silly putty:
    a. shape it (contour change)
    b. cut it (separation change)
    c. let it dry (internal change)
    d. put two pieces together (addition change).

    Note: Use some of the playdough toys to demonstrate these conversion processes. It not only provides for good visual aids, but also allows for excellent simulations of many industrial processes, which you will be studying later.

4. Others to be identified by the instructor—including future laboratory activities.

    Note: As the instructor is using examples to reinforce the concepts of material conversion, he/she should also identify and explain the material characteristics and properties that are being overcome or changed during the material conversion. The instructor should draw the students into the discussion by asking them to describe what is happening to the material during conversion.

DAY **ACTIVITY**

5. Have the students describe the addition, separation, contour, and internal changes used in selected processes identified by the instructor, such as:
   a. stapling two pieces of paper together
   b. bending a paper clip
   c. making jello
   d. sharpening a pencil
   e. nailing two boards together
   f. making a screwdriver.

6 Introduce and discuss the industrial classifications of manufacturing processes. They include: casting, molding, forming, separating, assembling, conditioning, and finishing.

The introduction and discussion should focus on developing an awareness and understanding of the concepts, principles, or factors to be considered in each identified classification (see Introduction to this module or the Materials and Processes Outline in the Appendix for details).

7-8 Note: The "concept frame" (poster) activity described herein is a suggested activity. Any teacher-developed laboratory activity capable of providing the student the opportunity to demonstrate his/her comprehension of the introductory material may be substituted.

Introduce concept frame activity. This activity encourages and allows each student the opportunity to communicate to the instructor and others that he/she has developed an understanding of material presented during this introduction.

The criteria for, or objective of the concept frame, is that it be capable of communicating to others visually, in a limited amount of space, one of the concepts, characteristics, operations, or classifications discussed during the introduction to Manufacturing Materials and Processes Course. The completion of this activity will require the learner to comprehend and internalize information presented and then develop a visual concept frame capable of communicating this information. The concept frame can include drawings, pictures out of magazines, three-dimensional objects, verbage, or any other media necessary to get the message across. The only limitation is the size of the posterboard and the fact that the materials must be mounted on it.

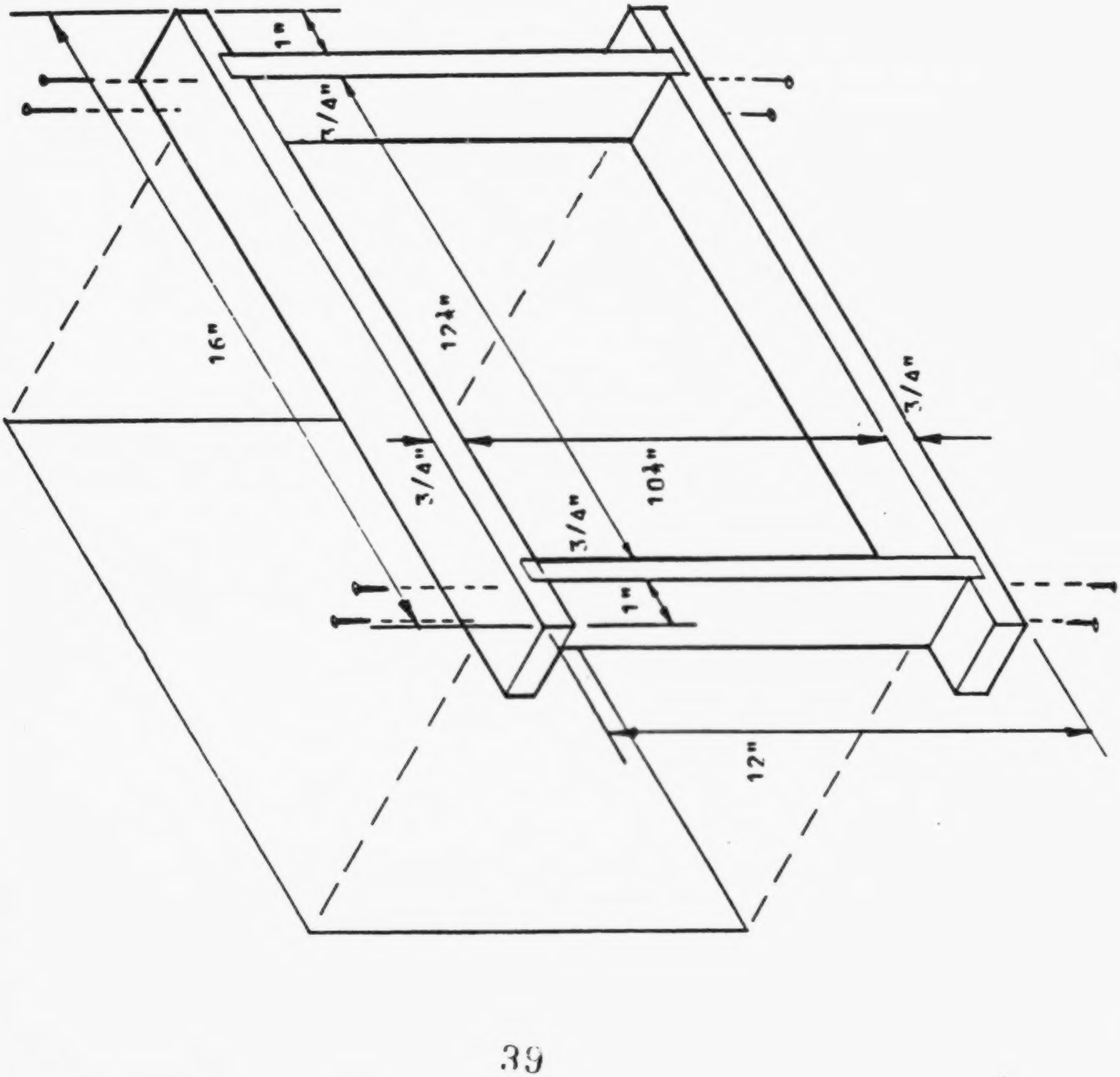
DAY **ACTIVITY**

The visual will later be mounted on a wood frame produced during a separation activity (thus the name "concept frame"). Suggested size for the posterboard on which the student will develop his/her idea is 11 X 14. (See Appendix.)

Establish due date for assignment (recommend seven days--two days in class and five days outside of class).

Assist students in formulating ideas and making sketches of their proposed "concept frame." Sketch should be a visual representation of what the concept frame will look like when completed. It should depict wording, symbols, and approximate layout of all materials to be used to communicate the idea. Sketches should be approved before the student proceeds.

Help students gather materials and build their concept frames.


1"
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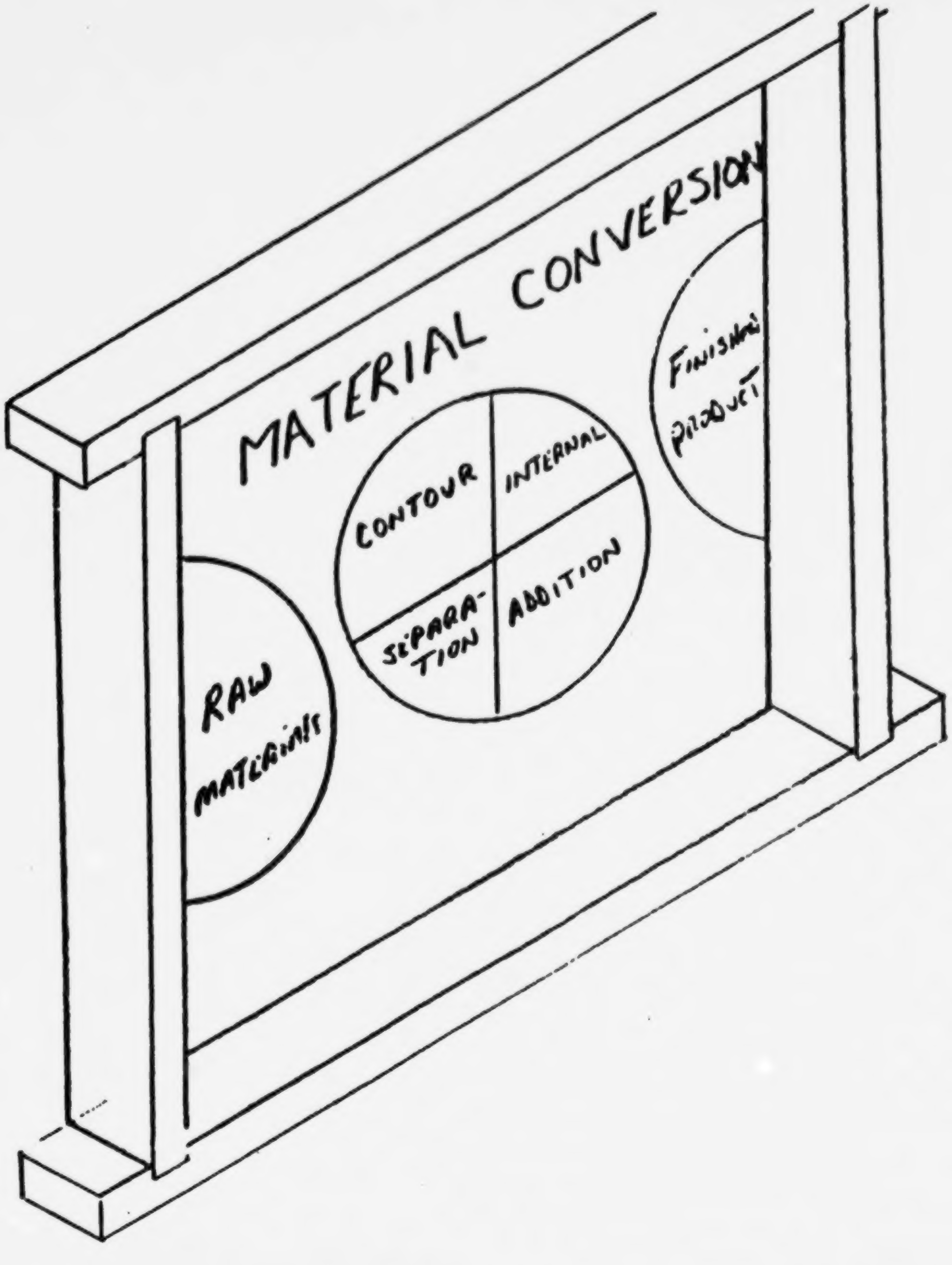
3/4"
3/4"
10¼"
1"
12"


MATERIAL CONVERSION
RAW MATERIALS
CONTOUR
INTERNAL
SEPARATION
ADDITION
FINISHED PRODUCT

CONCEPT FRAME SIZED TO
FIT POSTER BOARD

BIBLIOGRAPHY

TEXTBOOKS

Kazanas, H. C., G. Baker, and Gregor, Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 12-20, 48-77.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 7-21.

References

Kazanas, H., R. Klein, and J. Lindbeck, Technology of Industrial Materials, Bennett Publishing Co., Peoria, IL, 1974, pp. 6-34.

Todd, R., D. McCrory, and Todd, Understanding and Using Technology, Davis Publishers, Worcester, MA, 1985, pp. 33-78.

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MANUFACTURING MATERIALS AND PROCESSES

MODULE: 2 : Nature of Manufacturing Materials

LENGTH: 7 DAYS Manufacturing CLUSTER

"Materials are important for our survival and realizing our dreams. People use materials to make things that are needed for safety and comfort. People use materials to feed themselves, build shelters, raise cities, and journey across oceans and into space."

To understand technology, we must also understand materials. Materials are used to build our machines. Materials are then changed by these machines to make products. Materials are used to supply energy that we need for production, transportation and communication. Materials are the basic ingredients of technology.

Early humans had only natural materials to work with. Later, manufactured or synthetic materials were developed. (Todd, McCory, and Todd, pp. 33-34)

Solid, natural, and synthetic materials commonly referred to as engineering materials, can be grouped into four families: (1) polymeric, (2) metallic, (3) ceramic, and (4) composite. Each of these materials has certain properties and characteristics that are dependent upon the material's chemical and physical structure. Polymer materials are often subdivided into two (2) subgroups: (1) natural (wood), and (2) synthetic (plastics). However, many material engineers consider wood to be a natural composite. Metallics are traditionally grouped into ferrous and nonferrous. Stone, cement, glass, clay, oxides, and carbides, are all sub-families of ceramic materials. Composite materials can be grouped according to their physical structure: fiber, particle, laminate, flake, and filler.

When analyzing the nature of materials, topics such as atomic theory, bonding, and structure should be investigated to further the students' understanding of industrial materials. To understand the nature and structure of a material, it is helpful to understand what makes materials similar. All materials are made up of electrons, protons, and neutrons (atoms). These atoms are bonded (covalent, ionic, metallic, and Van der Walls Forces) together to form elements, molecules, compounds, platelets, crystals, etc., in the form of gases, liquids, and/or solids. The type and manner in which these atoms are bonded together determines the properties and characteristics of a material.

"Thousands of different materials are used by industry. Engineers and designers must know how to choose the right material to make a useful product. In order to compare different materials scientifically, specific testing standards (ASTM) have been established. These test procedures help to classify materials and also help determine where they can or cannot be used." (Thode, p. 1). Destructive and non-destructive tests can be used to investigate many of these material properties and characteristics. These properties include: mechanical, physical, thermal, chemical, electromagnetic, optical, acoustical, physicochemical, processing, service, and environmental.

The content of this module should be centered around the families of industrial materials, their subgroups, nature and atomic structure of materials, and their properties and characteristics. Care should be taken to ensure that each concept, characteristic or property, is understood before proceeding to the next because of the necessity to build a strong knowledge base or foundation in each area. Introduce the student to each topic using a broad array of examples. Principle emphasis should be placed on the concepts and principles under discussion, rather than individual material families, subgroups, and properties.

The module is organized to introduce the learner to manufacturing materials, their characteristics and properties, methods of testing and inspection, and selection and use during the first stages of the module. During the body of the module, students will be involved in several learning experiences and laboratory activities designed to reinforce the material under discussion. At the end of the module, the students should enter into a review session where they can compare, contrast and apply the concepts and principles developed during the module.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe a material.
2. Define and describe an engineering material.
3. Identify, describe, and give examples of material characteristics and properties.
4. Identify and describe the atomic nature and structure of materials.
5. Contrast and compare the characteristics of selected industrial materials.
6. Identify and describe the major classifications of destructive and nondestructive tests.
7. Discuss the impact(s) of producing and utilizing manufacturing materials on the environment and society.
8. Be aware of the relationship(s) between product function, material characteristics and properties, material selection, and material processing.
9. Identify and describe monolithic materials, material systems, and dynamic materials.

DAY	**ACTIVITY**
1	Introduction, discussion, and review of manufacturing materials. 1. What is an engineering material? 2. Importance of materials 3. Material characteristics and properties 4. Material processing, service requirements, and environmental impacts
2-3	Discussion of material families. 1. Demonstration and discussion of material characteristics 2. Demonstration and discussion of material properties 3. Comparison of material characteristics and properties between materials and families
4	Material identification, classification, sorting, and labelling activity.
5	Introduction and discussion of the nature of industrial materials. 1. Atomic theory 2. Atomic bonding 3. Material structure 4. Material behavior under stress
6-7	Preparation for and presentation of student presentations on: 1. Material families 2. A particular material 3. A particular material property or characteristic

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module: Develop or update your daily lesson plans, generate handouts, collect examples, select the media and materials necessary to support your instruction, and determine activities capable of supporting the module.

Identify, develop, and/or test examples, equipment, and procedures that will be used to demonstrate or reinforce selected material characteristics and/or properties.

1 Introduce and review manufacturing materials.

Define, discuss, and show examples of:

1. a material
2. an engineering material
3. the importance of materials to people and technology
4. the characteristics and properties of materials
5. the families or types of materials.

See Introduction to this module, and Material and Processes Outline in Appendix, and review suggested texts and references.

Introduce and discuss the topics of material processing, material service requirements, and environmental impacts.

The processing discussion should focus on a material's ability to be: machined, formed, welded, cast, drawn, conditioned, finished, joined, tooled, fused, forged, molded, etc., through the manipulation or overcoming of one or more material properties and/or characteristics.

The discussion of material service requirements should include topics such as: integrity of shape, strength, service life, special functions, cost, processing, environmental effects, etc.

The discussion of environmental impacts on individuals, society, and environment should include: expected, desirable, unexpected, undesirable.

Have students collect five different materials for Day 4 activity.

DAY **ACTIVITY**

2-3 Discuss material families and types.

Review, discuss, and give examples of material families:

1. Metallics—ferrous, nonferrous, metallic structures, metallic properties, etc.
2. Polymers
   a. natural polymers—structure of wood (hardwood and softwood, porosity), properties of wood, wood standards and classifications, etc.
   b. synthetic polymers—structure of plastics (thermosets, thermoplastics, elastomers, polymer chains, linear polymers, branched polymers, cross-linked, polymer chains), properties of plastics, etc.
3. Ceramics—raw materials and structure, ceramic properties, types, etc.
4. Composites—structure of composites (fiber, particle, laminate, flake, filler), properties of composites, etc.

Discuss and explain the properties and characteristics of each family of materials.

Give and/or demonstrate examples of the following properties:

1. physical
2. thermal
3. chemical
4. electromagnetic
5. optical
6. acoustical
7. physio-chemical properties.

(See Materials and Processes Outline in the Appendix for details.)

Discuss and/or demonstrate examples of mechanical material characteristics, such as tension, compression, shear, stiffness, elasticity, plasticity, ductility, brittleness, hardness, creep, fatique, torsion, flexure, and endurance for each family.

4 Divide the class into groups of three-four. Have each group identify the family of materials to which each of its collective samples belong. Have each group label its samples.

DAY	ACTIVITY

5 Lead discussion on the nature of materials.

Identify, discuss, and give examples of:

1. atomic theory—atoms, electrons, periodic table, electron shell, shell theory, etc.
2. atomic bonding—chemical activity, physical states, atomic bonding, chemical changes, covalent bonds, ionic bonds, metallic bonds, Van der Walls Forces, bonds, etc.
3. structure of materials—atoms, electrons, molecules, compounds, elements, solids, liquids, gases, molecular chains, polymers, platelets, crystals, materials types or families, etc.
4. behavior of materials—under loads, to applied fields, to stress and strain, to thermal energy, to chemical activity, to acoustical energy, environmental factors, etc.

6-7 This module has investigated and discussed indepth the material families of metallics, polymers, ceramics, and composites. As a form of review, each student should prepare and give a demonstration that will illustrate a particular material property or characteristic of an identified material. The students' presentation should:

1. identify the material to be used
2. identify and describe the property or characteristic to be demonstrated
3. demonstrate the identified material property or characteristic
4. be no longer than two minutes.

This activity should be discussed at the end of Day 5. The student should come to class the next day with a material and material characteristic or property to be illustrated or demonstrated. Class time should be made available during Day 6 for the student to develop and clarify his/her ideas with the instructor and/or plan, and prepare his/her demonstration procedure and/or device.

Students should come to class on Day 7 prepared to give their presentation, and to answer questions regarding the identified material and property or characteristic, to be demonstrated.

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Todd, R., D. McCrory, and Todd, Understanding and Using Technology, Davis Publishers, Worcester, MA, 1985, pp. 33-55.

MODULE: 3 : Testing Materials

LENGTH: 15 DAYS Manufacturing CLUSTER

Module 2 identified the significance and importance of industrial materials. Almost every known element is used in some manner in modern manufacturing processes and materials. These materials are used to make the industrial machines, which are in turn, used to produce industrial and consumer goods and services. To have a thorough understanding of manufacturing and to choose the right material to improve the performance of tools, machines, equipment, and structures, one must understand the characteristics and properties of its materials.

Material testing is typically divided into two categories: destructive and nondestructive. In destructive testing, the specimen is damaged during the performance of the test, usually to a degree where it cannot be used again (i.e., tensile, shear, compression, hardness, bend, etc.). Destructive testing, is used primarily to evaluate or determine the mechanical characteristics of a material. Nondestructive testing does not damage the specimen and is used to evaluate, locate, and/or determine internal and external defects, and other physical properties (i.e., thermal, optical, physical, acoustical, etc.). Nondestructive testing is commonly referred to as inspection of materials and products.

In contrast to destructive testing, nondestructive tests do not damage or destroy the specimen or product being evaluated. Thus, "any test that does not destroy the specimen can be classified as nondestructive." Nondestructive tests are used primarily to identify and locate defects in specimens and products, in contrast to destructive tests that are used to measure or determine the limits of a particular characteristic. Nondestructive tests seldom duplicate environmental or other stress conditions, whereas destructive tests, often simulate environmental conditions while placing the specimen under stress. Although commonly used to detect defects, recent technological developments are increasing the ability of nondestructive tests to determine material properties and characteristics. Common nondestructive tests include: visual, radiographic, electrical, ultrasonic, acoustic, liquid penetrant, magnetic, and eddy current. (Kazanza and others, pp. 318-326)

Liquid penetrant and magnetic particle inspection fit into production environments and situations requiring the inspection for surface checks on nonporous materials efficiently, because they are fast, simple, and have low initial equipment and training costs. Ultrasonic tests are a quick and sensitive method to measure sizes, shapes, and locations, and to determine variations in structure and properties of a material. Radiographic tests include gamma and x-ray techniques. These techniques are often comparatively costly, bulky, and inconvenient, and pose potential health hazards. However, radiographic tests have the advantage of recording, photographically, the exact size, shape, and location of an internal defect within a material.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe destructive and nondestructive testing.
2. Identify and describe the potential variables affecting destructive and nondestructive tests.
3. Identify and describe selected material properties and characteristics that will affect the performance of a specimen or product.
4. Identify and describe at least ten destructive and/or nondestructive tests.
5. Identify, describe, and give examples of how selected material characteristics and properties could be evaluated.
6. Contrast and compare the characteristics and properties of selected engineering materials.
7. Perform selected destructive and nondestructive tests using student, teacher, and/or commercially developed test equipment.
8. Evaluate and determine selected material characteristics and properties.
9. Discuss the impacts of improper determination or evaluation of specimen characteristics and/or properties.
10. Compare and contrast selected destructive and nondestructive tests.

CALENDAR

DAY	ACTIVITY
1	Introduction to and discussion of destructive and nondestructive testing and inspection. 1. Discussion of stress and strain. 2. Discussion and demonstration of tensile and compression characteristics and tests.
2	Introduction to, discussion, and demonstration of material hardness, impact characteristics, and tests.
3	Introduction to, discussion, and demonstration of material shear, bend, fatigue, creep, torsion, mechanical fastener, and/or glue line shear or cleavage characteristics, and testing procedures.
4-9	Student laboratory activities related to material hardness, impact, shear, bend, fatigue, creep, torsion, mechanical fastener, and/or glue line shear or cleavage characteristics, and testing procedures.
10	Introduction to, discussion, and demonstration of nondestructive material inspection, testing methods, and/or procedures.
11	Continued discussion and demonstration of nondestructive material inspection ,testing methods, and/or procedures. Demonstration and assigning of laboratory activities.
12-14	Observation of and assisting students working on nondestructive material inspection, testing methods and procedures.
15	Review and summarizing of destructive and nondestructive testing results and procedures.

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module, develop or update your daily lesson plans, generate handouts, collect examples, select the media and materials necessary to support your instruction, and determine activities capable of supporting the module content.

Identify, develop, and/or test examples, equipment, and procedures that will be used to demonstrate or reinforce selected material characteristics and properties.

Develop and/or acquire six-ten individualized, destructive testing laboratory activities, capable of supporting the study of manufacturing materials. Individualized activities should be capable of guiding the learner through the activity with little or no assistance from the instructor. Destructive testing activities should be capable of supporting and developing an understanding of tensile, compression, impact shear, hardness, flexure, torsion, cleavage, creep, mechanical fastener strength, characteristics, and on a broad selection of engineering materials.

Develop and/or acquire five-eight individualized nondestructive testing laboratory activities, capable of supporting the study of manufacturing materials. Activities should be capable of supporting and developing an understanding of common nondestructive tests, inspections, and evaluation procedures such as: visual inspection, radiographic, electrical, ultrasonic, acoustic, liquid penetrant, magnetic, eddy current, moisture content, size, shape, electrical and thermal conductivity, etc. on a broad selection of engineering materials.

Obtain and/or prepare materials for selected laboratory activities...on specified work days have appropriate laboratory activities set up before class is scheduled to begin.

1 Introduce destructive and nondestructive testing.

Identify and discuss destructive test variables and/or considerations...loading methods, temperature, accuracy, field or laboratory, economy, and procedures.

Introduce and discuss ASTM (American Society for Testing and Materials) standards for testing materials.

DAY **ACTIVITY**

Define and discuss stress and strain.

Describe, review, and discuss tensile and compression characteristics and testing—proportional limit, yield point, ultimate strength, breaking strength, tensile strength, compression strength, L/D ratio.

Discuss similarities between compression and tensile tests.

Demonstrate tensile destructive test on a metallic material. Point out elongation, reduction of area, gauge length, elastic limit.

Discuss common types of material failure when subjected to tensile loads (stresses).

Identify common products and structures that are often subjected to this type of stress.

Demonstrate compression test on a ceramic or natural polymer. Point out brittleness, fracture, L/D ration.

Discuss common types of material failure when subjected to compression loads (stresses).

Identify common products and structures that are often subjected to this type of stress.

Students should record the procedures and safety practices introduced in the demonstrations.

2 Introduce hardness and impact testing.

Discuss and demonstrate hardness testing. The purpose of hardness testing is to measure and evaluate a material's resistance to localized penetration or scratching. This resistance to localized penetration (hardness) is the result of a combination of other characteristics such as: elasticity, ductility, brittleness, and toughness.

Types of penetration hardness testers include:
1. Brinell
2. Rockwell
3. Vickers
4. Micro Hardness.

DAY	ACTIVITY

Other types of hardness tests include:

1. scratch—file and Mohs tests
2. rebound.

Identify common products and structures that are often subjected to this type of stress.

Discuss and demonstrate impact testing. Impact testing measures and evaluates a material under dynamic loads. The main purpose of this type of test is to measure the amount of energy absorbed by a material during its fracture by a dynamic impact load. The characteristic associated with and measured by impact testing is toughness. (Example—a piece of steel is tougher than a piece of pottery because more energy is absorbed during the fracture of the steel than by the pottery.)

Factors affecting an impact test include:

1. the type and shape (form) of the material used
2. the velocity and weight of the load striking the specimen
3. the conditions under which the test is conducted.

Types of impact tests include:

1. tension
2. charpy
3. izod

(Kazanas and others, pp. 297-318)

Discuss common types of material failure when subjected to impact loads (stresses).

Identify common products and structures that are often subjected to this type of stress.

The students should record the procedures and safety practices introduced during the demonstrations.

3 Introduce shear, flexure (bend), fatigue, creep, torsion, mechanical fastener, glue line, and other appropriate testing procedures and concepts. (See Introduction to this module and Material and Processing Outline in the Appendix.)

DAY **ACTIVITY**

Discuss and demonstrate shear, flexure, and other appropriate testing and evaluation concepts, procedures, and equipment.

Discuss and demonstrate bend testing. Bend testing, also called a flexure test, is frequently performed to evaluate a cross-sectional design rather than the strength of the material being used. However, properties such as modules of fracture, modules of elasticity, deflection, and ductility of a material and/or specimen, can also be measured and evaluated.

Typical material specimens include:

1. round
2. rectangle.

Common tests include:

1. free bend tests
2. semi-guided bend tests
3. guided bend tests.

Discuss common types of material failure when subjected to bend loads (stresses).

Identify common products and structures that are often subjected to this type of stress.

Discuss and demonstrate shear testing. Shear testing usually places a specimen under strain by applying stresses (load), acting parallel to the specimen, but in opposite directions. These opposing forces cause a portion of the specimen to slip (slide) past another (Kazanas and others, pp. 294-305).

Discuss common types of material failure when subjected to shear loads (stresses).

Identify common products and structures that are commonly subjected to this type of stress.

Identify and discuss types of failure and products associated with other forms of destructive testing.

Students should record the procedures and safety practices introduced during demonstrations.

DAY **ACTIVITY**

4 Days 4-9 are a suggested sequence for method of content delivery and reinforcement. Any sequence of activities developed by the instructor that is capable of delivering and reinforcing destructive testing content and objectives can be used.

Introduce and discuss individualized destructive testing laboratory activities selected and developed for this module (some may be examples demonstrated earlier).

Note: Recommend a minimum of six activities for a group of twenty students. Number of recommended activities is based on the assumption that students will be working in groups of two. Therefore, the possibility exists that all students will not perform the same activities. However, each student should complete an identified core of activities. Rotate students through activities.

Assign and supervise students as they begin their laboratory activities.

5-9 During the beginning of class, discuss, demonstrate, and help students to make the necessary calculations for plotting and determining characteristics and properties being investigated.

Observe and assist students working on destructive testing activities.

Students should work on destructive testing activities, determine and record results and conclusions of the activity.

Rotate to an instructor-approved activity when completed with the assigned activity.

10 Introduce and review non-destructive testing.

Introduce and discuss selected nondestructive tests, inspection, and/or evaluation procedures, such as:

1. Visual inspection—oldest and most widely used inspection technique.
2. Radiographic inspection—basically a photographic process using x-rays or gamma rays instead of visible light to locate internal flaws.
3. Magnetic particle inspection—detects surface and subsurface flaws in ferrous metals and alloys by observing the magnetic field which is disturbed by the flaws (resulting in an accumulation of magnetic particles).

DAY	ACTIVITY
	4. Ultrasonic testing—uses sound waves, beamed into the specimen or product, to locate internal flaws. 5. Acoustic emission testing—monitors flaws or cracks as they develop by "listening" to the specimen, product, or structure. 6. Liquid penetrant testing—is used to detect surface flaws and cracks through the use of a penetrant and developer. 7. Eddy current testing—is used to detect flaws near the surface by inducing an alternating magnetic field in the specimen, and then monitoring the induced current.
	Students should record procedures and safety practices presented during demonstrations.
11	Continue discussion of selected nondestructive tests, inspection, an/or evaluation procedures by examining the procedures used to test, inspect, and evaluate material characteristics and properties such as:
	1. moisture content 2. size (measuring) 3. shape 4. mass 5. electrical conductivity 6. thermal conductivity 7. chemical 8. optical 9. density 10. surface texture 11. specific gravity 12. macro-micro structure 13. porosity 14. absorption 15. internal and external flaws and defects.
	Identify selected materials, characteristics, properties, and defects which each nondestructive procedure is commonly used to evaluate.
	Demonstrate selected nondestructive tests, inspection techniques, and evaluation procedures.
	Introduce and discuss individualized nondestructive testing laboratory activities selected and developed for this module (some may be examples demonstrated earlier).

DAY	ACTIVITY
	Note: Recommend a minimum of ten activities for a group of twenty students. Number of recommended activities is based on the assumption that students will be working in groups of two. Therefore, the possibility exists that all students will not perform the same activities. However, each student should complete an identified core of activities. Rotate students through activities.
	Assign and supervise students as they work on their laboratory activities.
12-14	Observe and assist students working on nondestructive testing activities.
15	Review and summarize destructive and nondestructive testing and results of individualized, nondestructive test. Draw students into review and discussion to ensure that all students become aware of the concepts of all identified tests, and the results and conclusions drawn from those tests. Also, compare the results of identified tests that were conducted by more than one group and evaluate their reliability and validity.

TEXTBOOKS

Kazanas, H. C., G. Baker, and Gregor, Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 48-77, 88-92.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 21-41.

References

Kazanas, H., R. Klein, and J. Lindbeck, Technology of Industrial Materials, Bennett Publishing Co., Peoria, IL, 1974, pp. 281-377.

MODULE: 4 : Casting and Molding Materials

LENGTH: 9 DAYS Manufacturing CLUSTER

Casting and molding is a classification of secondary manufacturing processes which provides size and shape to a part by introducing a molten, plastic state, or powdered material, into a prepared mold and allowing or causing it to solidify before being extracted from the mold. Metallic, ceramic, plastic, composite parts, and products can be produced using a variety of casting and molding processes.

All casting and molding processes involve a five-step sequence. The sequence forms the foundation for a conceptual understanding and study of industrial casting and molding processes. These steps are:

1. A permanent or expendable mold is prepared.

2. The material is prepared by melting, dissolving/suspending, or adding agents to liquids.

3. The material is introduced into the cavity using gravity or other forces (i.e., pressure, vacuum).

4. The material is caused to solidify by cooling/freezing, drying, or chemical action (conditioning).

5. The product is extracted by either destroying the mold or opening the mold and extracting or ejecting the part.

The content for this module should be centered around the variations in the identified five-step sequence as it is applied to casting and molding processes for a number of different materials. Care should be taken not to overemphasize a single type of material such as metallics of even a specific type such as aluminum. Nor should all casting be made in expendable molds (i.e., sand casting, into which molten metal is poured.).

Introducing students to a broad array of possibilities within each of the five steps should be the goal of the instructor. Also, principal emphasis should be placed on the concepts within the five steps as opposed to the specific skill needed to complete one or two selected products.

The module is organized to introduce students to the secondary processes of casting and molding during the first stages of the module. Later in the module, each student will complete several laboratory-centered casting and molding processes, utilizing several different materials. These processes should reinforce the content and five-step sequence of casting and molding. The number of castings and moldings completed will vary with time, student abilities, and other similar factors. Finally, the student should enter into a review session where the concepts of casting and molding are reinforced and various casting and molding processes are compared and contrasted.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe casting and molding.
2. Describe the five-step sequence used in producing all cast and molded products.
3. Describe the two types of molds used in casting and molding material conversion processes.
4. Describe the major methods used to prepare materials for introduction into molds.
5. Describe common techniques used to introduce materials into molds.
6. Describe ways to solidify materials which have been introduced into molds.
7. Describe methods of removing cast, molded parts, and products from expendable and permanent molds.
8. Describe the procedure to produce products using selected casting and molding techniques.
9. Produce a cast or molded product or part using one or more selected material conversion processes.
10. Compare and contrast the procedures and outputs of selected casting and molded activities.
11. Describe the input-process-output relationship for casting and molding processes.
12. Discuss the impacts of casting and molding processes and industries on individuals, society, and the environment.
13. Be aware of the careers and career ladders for employees involved in casting and molding.

CALENDAR

DAY	ACTIVITY
1	Introduction to and discussion of casting and molding manufacturing processes. 1. Casting and molding principles. 2. Demonstration of casting and/or molding processes.
2	Review and discussion of casting and molding principles. 1. Demonstration of casting and/or molding processes. 2. Assigning of student casting and molding laboratory activities.
3-4	Student casting and molding laboratory activities. Observation of and assisting students working on casting and molding activities.
5	Review and discussion of casting and molding principles. Demonstration of casting and/or molding processes.
6	Demonstration of casting and/or molding processes. Assigning of student casting and molding laboratory activities.
7-8	Student casting and molding laboratory activities. Observation of and assisting students working on casting and molding activities.
9	Student casting and molding laboratory activities. 1. Observation of and assisting students working on casting and molding activities. 2. Review and discussion of casting and molding principles.

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module, identify, develop, and/or test material or product samples, equipment, and procedures that will be used to demonstrate or reinforce the understanding of casting and molding processes, and the five-step casting and molding sequence.

Record these procedures and identify specific safety considerations for each.

Give reading assignments prior to Day 1.

Develop and/or acquire six-eight individualized casting and molding laboratory activities capable of guiding the learner through the activity with little assistance from the instructor. Activities should support and develop an understanding of casting and molding processes and the five-step sequence used to perform them.

These activities should use both permanent and expendable molds; and metallic, ceramic, composite, and polymer materials. Also, consider using materials that must be suspended, melted, and compounded. Select processes should include activities that use force or gravity to introduce the material into the mold.

Obtain and/or prepare materials for selected laboratory activities.

1 Introduce and discuss "Casting and Molding Industrial Materials." This presentation should set the stage for the module, the introduction, and investigation of the five-step sequence of casting and molding. (Presentation should be 10-20 minutes in length.)

The five-step sequence of casting and molding material conversion processes is as follows:

1. A permanent or expendable mold is prepared.
2. The material is prepared by melting, dissolving/suspending, or adding agents to liquids.
3. The material is introduced into the cavity using gravity or other forces (i.e., pressure, vacuum).
4. The material is caused to solidify by cooling/freezing, drying, or chemical action (conditioning).
5. The product is extracted by either destroying the mold or opening the mold and extracting or ejecting the part.

Emphasis should be placed on the concept of casting and molding rather than the specific steps needed to make a single type casting.

DAY **ACTIVITY**

Discuss casting and molding activities to be used during this module and demonstrate one of these using it as an example to reinforce the principles in the five-step sequence.

2 Review and discuss the five-step sequence of casting and molding.

Reinforce the discussion by demonstrating additional casting and molding activities that will be used during this module. As activities are being demonstrated, describe how each step in the procedure is applicable to the five-step sequence.

Typical activities could include:

1. green sand casting (metal or wax)
2. slip casting (ceramic)
3. injection molding a part for a product to be completed later (checkers for a checkerboard, hinges for a box, etc.)
4. casting a plaster (sawdust and plaster) composite plaque.

The instructor may want to divide the class into groups of two-four students. Each group can then complete a casting or molding process and move (rotate) to the next activity when completed. Each student should complete an Activity Analysis Sheet when completed with an assigned activity.

This method of class management is suggested because no one facility will likely have enough equipment and material to allow all students to perform the same activity at the same time. This will require the demonstration of activities in groups. One group of activities during the beginning of the module and a second group later.

Students should record procedures and safety practices introduced during the demonstrations.

3-4 Days 3-4 and 7-9 are a suggested sequence or method of content delivery and reinforcement. Any sequence of activities developed by the instructor can be used that is capable of delivering and reinforcing casting and molding module content and objectives.

Introduce, demonstrate, and/or discuss casting and molding laboratory activities selected and developed for this module.

Students should work on the laboratory activities and prepare Activity Analysis Sheets. (Typical sheets are available in the student laboratory manual for: Wright, R. T., Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1984.)

DAY **ACTIVITY**

5 Briefly (20-30 minutes) discuss five-step sequence of casting and molding processes as they relate to selected identified industrial processes.

Potential processes to be discussed could include:

1. investment casting
2. shell molding
3. ceramics molding
4. rotational molding
5. slush and slip casting
6. dip molding
7. centrifugal casting
8. die casting
9. injection molding
10. blow molding
11. continuous casting
12. compression molding
13. transfer molding
14. green sand casting
15. placing concrete
16. centrifuge.

Student should continue with laboratory activities or view a film illustrating casting processes.

6 Introduce, demonstrate, and discuss additional casting and molding laboratory activities selected and developed for this module.

Emphasize five-step sequence of casting and molding processes as they relate to the identified laboratory activities being demonstrated.

Students should take notes on both the procedures and safety considerations, and participate in the discussion.

7-9 Observe and assist students as they complete casting and molding activities and prepare Activity Analysis Sheets.

Take the last 10-20 minutes of Day 9 to review and discuss casting and molding laboratory activities and related industrial processes.

Discuss impacts of casting and molding processes and industries on individuals, society, and the environment.

APPENDIX

SPECIAL INSTRUCTION MATERIALS

A casting and molding laboratory activity analysis sheet should be designed for the student:

a. identify and describe the industrial, social, and economic advantages and disadvantages of the identified process

b. identify and describe the materials being converted

c. identify and describe how the permanent or expendable mold was prepared

d. identify and describe how the material was prepared (melting, dissolving/ suspending, or adding agents to liquids)

e. identify and describe how the material was introduced into the cavity (using gravity or other forces, example: pressure, vacuum)

f. identify and describe how the material was caused to solidify (by cooling/ freezing, drying, or chemical action, conditioning)

g. identify and describe how the product was extracted from the mold (by either destroying the mold or opening the mold and extracting or ejecting the part)

h. record safety consideration

i. record observations made during the activity and concerning the finished part or product. Reasons for defects should be considered and described.

SPECIAL EQUIPMENT AND SUPPLLIES

1. The following materials are not required, but will provide better learning opportunities for the students.

a. injection molder with molds
b. slip casting molds and prepared slip
c. permanent (plastic or metal) candle molds and materials for making candles
d. hot plate and double boiler for melting wax
e. table top foundry unit for casting lead
f. materials to support tabletop foundry unit

g. other equipment, materials, and supplies capable of simulating or supporting laboratory activities or discussion of casting and molding processes such as:

1. investment casting
2. shell molding
3. ceremics molding
4. rotational molding
5. slush and slip casting
6. dip molding
7. centrifugal casting
8. die casting casting
9. injection molding
10. blow molding
11. continuous casting
12. compression molding
13. transfer molding
14. green sand casting
15. placing concrete
16. centrifuge
17. etc.

Suggested Textbooks

Kazanas, H. C., G. Baker, and Gregor. Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 93-104.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 43-98.

MODULE: 5 : Forming Materials

LENGTH: 9 DAYS Manufacturing CLUSTER

Forming is a classification of secondary processes which provide form to industrial materials by changing the size and shape, but not the volume of a material, by the application of force between its yield point and fracture points. There are literally hundreds of industrial forming processes that can be used to change the size and shape of industrial materials into industrial and consumer parts and/or products. However, all these processes and their numerous variables can be easily described and/or analyzed by examining three variables in the material conversion process. These variables include material preparation, shaping device, and contouring force.

The content for this module should be centered around the three variables as they are applied to forming processes for a number of different engineering materials. These variables and their related subcomponents include:

1. Material preparation
   a. hot
   b. cold
   c. other.
2. Shaping device
   a. open die
   b. closed die
   c. mated die
   d. one piece
   e. roll.
3. Contouring force
   a. forms (i.e., hydraulic, mechanical, static, dynamic, etc.)
   b. applied between yield and fracture points.

Care should be taken not to overemphasize a single type of material such as metallics or even a specific type such as steel, nor should all forming processes be performed cold.

Introducing students to a broad array of possibilities within each of the three variables should be the goal of the module. Also, principle emphasis should be placed on the concepts within the three variables as opposed to the specific skill needed to complete one or two selected products.

The module is organized to introduce students to the secondary processes or forming during the first stages of the module. Later in the module, each student will complete several laboratory-centered forming processes utilizing several different materials. These processes should reinforce the content and the three variables of forming processes. The number of forming activities completed will vary with time, student abilities, and other similar factors. Finally, the student should enter into a review session where the concepts of forming processes are reinforced, and various forming processes are compared and contrasted.

CALENDAR

DAY	ACTIVITY
1	Introduction to and discussion of manufacturing forming processes. 1. forming principles and variables 2. demonstration and discussion of forming processes and principles
2	Review and discussion of forming principles and variables. 1. demonstration and discussion of forming processes 2. assigning of forming student laboratory activities
3–4	Conducting forming laboratory activities. Observation of and assisting students working on forming activities.
5	Review and discussion of forming principles and variables. 1. introduction and discussion of industrial forming processes 2. demonstration of forming laboratory activities
6–8	Conducting forming laboratory activities. Observation of and assisting students working on forming activities.
9	Review and discussion of forming laboratory activities. 1. discussion of environmental and social impacts 2. careers and career ladders 3. discussion of laboratory activities, results, and related procedures

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module, determine activities capable of supporting the module content.

Identify, develop, and/or test material or product samples, equipment, and procedures that will be used to demonstrate or reinforce the understanding of identified forming material conversion processes and principles. Record these procedures and identify specific safety considerations for each.

Develop and/or acquire eight-ten individualized, forming laboratory activities, capable of supporting the study of manufacturing processes. Individualized activities should be capable of guiding the learner through the activity with little or no assistance from the instructor. Activities should be capable of supporting and developing an understanding of forming material conversion processes, and the principle used to describe and analyze the forming of industrial engineering materials.

These activities should use hot, cold, and other methods of preparing materials for processing. Selected processes should utilize a variety of materials to include: Metallics, ceramics, composites, and polymers. Processes utilizing open dies, closed dies, mated dies, one piece dies, or rollers as the shaping devices, should be considered. Different forms of energy (contouring force) should also be taken into consideration when selecting laboratory activities.

Obtain and/or prepare materials for selected laboratory activities.

Identify and give students appropriate reading assignments before scheduled lectures, discussions, and/or demonstrations.

1 Introduce and discuss "Forming Industrial Materials." This presentation should set the stage for the module and introduce the three variables used to describe a forming process and the subcomponents of each variable. (This introduction should be approximately 15-25 minutes long.)

DAY **ACTIVITY**

The three variables and related subcomponents used to describe forming material conversion processes are as follows:

1. Material preparation
   a. hot
   b. cold
   c. other.
2. Shaping device
   a. open die
   b. closed die
   c. mated die
   d. one piece
   e. roll.
3. Contouring force
   a. forms (i.e., hydraulic, mechanical, static, dynamic, etc.)
   b. applied between yield and fracture points.

Emphasis should be placed on the concept of forming rather than the specific steps needed to make a single kind of shape or bend.

Discuss forming activities which will be used during this module.

Reinforce the discussion by demonstrating one of the forming processes (activities) that will be performed during this module.

As activities are being demonstrated, describe how each step in the procedure is applicable to the forming variables and their related subcomponents.

Typical activities might include:

1. drop forging a screwdriver
2. vacuum forming a product or part
3. forming a part or product utilizing flexible die forming
4. laminating a part or product using wooden members
5. high energy rate forming of a part or product
6. spinning a metallic part or product
7. rolling a part or product
8. extruding a part or product
9. pressing a part or product.

Students should record procedures and safety practices introduced during the demonstrations.

DAY **ACTIVITY**

2 Days 2-4 and 6-8 are a suggested sequence or method of content delivery and reinforcement. Any sequence of activities developed by the instructor can be used that is capable of delivering and reinforcing forming industrial materials module content and objectives.

The instructor may want to divide the class into groups of two-four students. Each group, as individuals, can then complete a forming process and move (rotate) to the next activity when completed.

This method of class management is suggested because no one instructor or facility will likely have enough equipment or material to allow all students to perform the same activity at the same time. This will require the demonstration of activities in groups. One group of activities during the beginning of the module and a second group later.

Note: Recommend a minimum of eight activities for a group of twenty students. Number of recommended activities is based on the assumption that students will work as individuals or in groups of two. Therefore, the possibility exists that all students will not perform the same activities. However, each student should complete an identified core of activities. Rotate students through activities.

Introduce, demonstrate, and discuss forming individualized instruction laboratory activities selected and developed for this module.

Assign laboratory activities and have students do their work. Some activities may need to be done as homework assignments (i.e., Activity Analysis Sheets).

3-4 Continue working on forming activities.

Observe and assist students as they complete forming activities and prepare activity analysis sheets.

Rotate students through additional activities.

5 Prepare and present a discussion on forming processes and their related subcomponents as they relate to selected identified industrial forming processes.

DAY **ACTIVITY**

Potential processes to be included in this discussion include:

1. pressing
2. drawing
3. bending
4. rolling
5. high energy rate forming
6. forging
7. extruding
8. braking
9. magnetic forming
10. powder metal compacting
11. flexible die forming.

Introduce, demonstrate, and discuss additional forming individualized instruction laboratory activities selected and developed for this module.

Emphasize the three forming variables and their related subcomponents as they apply to the identified laboratory activities being demonstrated.

Students should record procedures and safety practices introduced during demonstration.

6-8 Observe and assist students as they work on forming laboratory activities and complete Activity Analysis Sheets.

9 Review and discuss forming laboratory activities and other industrial processes not performed in class.

Discuss impacts of forming processes and industries on individuals, society, and environment.

SPECIAL INSTRUCTIONAL MATERIALS

A forming material conversion laboratory activity analysis sheet should be developed which will cause the student to:

a. identify and describe the industrial, social, and economic advantages and disadvantages of the identified process
b. identify and describe the material being converted
c. identify and describe how the material was prepared (heated, cooled, or other)
d. identify and describe the contouring device (closed die, mated die, one piece die, open die, or roll)
e. identify and describe how the product was deformed
f. record safety considerations
g. record observations during the activity and about the finished part or product. Reasons for defects should be considered.

SPECIAL EQUIPMENT AND SUPPLIES

1. The following materials are not required, but will provide better learning opportunities for the students:

   a. vacuum former
   b. forging or drop hammering equipment
   c. spinning equipment
   d. explsoion forming devices
   e. flexible die forming equipment
   f. extrusion equipment
   g. other equipment, materials, and supplies capable of simulating or supporting laboratory or duscussion of forming activities/processes such as:

      1. bending
      2. drawing
      3. rolling
      4. laminating
      5. magnetic forming
      6. pressing
      7. hot forming
      8. blow molding
      9. cold forming
      10. powder metal compacting
      11. swaging
      12. coining
      13. dry pressing
      14. ram pressing

Suggested Textbooks

Kazanas, H. C., G. Baker, and Gregor, Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 144-183.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 103-130.

MODULE: 6 : Separating Materials

LENGTH: 13 DAYS Manufacturing CLUSTER

Separation processes are classified as secondary material conversion processes which remove material for the purpose of changing its size, shape, volume, and/or surface finish. Separation processes are typically described as processes that remove material by producing a chip or a shearing action. Metallic, polymer, ceramic, and composite materials are usually processed in this manner during some point in the manufacturing process. In addition to the typical separation processes utilizing a wedge cutting action, other processes commonly referred to as nontraditional (i.e., lazer, EDM, and ECM), are gaining favor in the processing of new exotic materials and traditionally difficult-to-machine shapes.

The study of separation processes should involve discussion of factors affecting separation, chip formation, types of chip, cutting tools and materials, tool geometry, coolants, machine motions, and cutting speeds. But, because there are literally hundreds of separation processes, and with new separation processes being developed everyday, it would be impossible to study every separation process and variable. Therefore, this module will concentrate on the concepts or common principles of material conversion by separation. These common principles include:

1. types of separation processes
    a. shearing
    b. machining
    c. nontraditional.
2. types of cutting elements
    a. single point
    b. multiple point
    c. other medium.
3. cutting element or material motion(s)
    a. linear
    b. reciprocating
    c. rotary
4. coolants.
5. material or cutting element support.

The content for this module should be centered around these principles as they are applied to separation processes performed on a number of different engineering materials. The principles and their related subcomponents will, hopefully, help the learner to understand new and unfamiliar separation processes, and serve as a basis for transferring knowledge related to separation material conversion processes.

INTRODUCTION - Continued

Care should be taken not to overemphasize a single type of material such as wood or even a specific type such as pine, nor should all separation processes performed be of the machining classification.

Introducing students to a broad array of possibilities within each type of material removal should be the goal of the module. Also, principal emphasis should be placed on the principles of separation processes as opposed to the specific skill needed to complete one or two selected products.

This module is organized to introduce students to the secondary processes of separation during the first stages of the module. Later in the module each student will complete several laboratory-centered separation processes utilizing several different materials. These processes should reinforce the content and principles of separation processes. The number of separation activities completed will vary with time, student abilities, and other similar factors. Finally, the student should enter into a review session where the principles of separation material conversion processes are reinforced and various separation processes are compared and contrasted.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe a separation material conversion process.
2. Identify and describe the five principle elements of a separation process.
3. Identify and describe the three types of material separation.
4. Identify and describe the three types of cutting elements used in separation material conversion processes.
5. Identify and describe the three types of cutting elements and material motion found in a separation process.
6. Identify and describe the coolant utilized during a selected separation process.
7. Identify and describe how cutting elements and industrial materials are supported during the conversion process in selected separation processes.
8. Describe the procedure to produce parts or products using selected separation processes.
9. Produce parts or products using selected material conversion separation processes.
10. Compare and contrast the procedures and outputs of selected separation processes.
11. Discuss the impacts of separation material conversion processes and industries on individuals, society, and environment.
12. Describe the input-process-output relationship for identified separation processes.
13. Be aware of the careers and career ladders for employees involved in separation processes.

CALENDAR

DAY	ACTIVITY
1	Introduction to and discussion of separation manufacturing processes. 1. discussion of separation processes and principles 2. demonstration and discussion of separating processes and principles.
2	Show and discuss a film illustrating examples of industrial separation processes.
3	Review and discussion of separating principles and processes. Demonstration and discussion of separation processes and principles.
4	Assigning and conducting separation laboratory activities.
5-6	Conducting separation laboratory activities. Observation of and assisting students working on separation activities.
7-8	Review and discussion of separation principles and laboratory activities. 1. introduction and discussion of industrial separation processes 2. demonstration and discussion of separation laboratory activities and principles
9-12	Conducting separation laboratory activities. Observation of and assisting students working on separation activities.
13	Review and discussion of separation laboratory activities and principles. 1. discussion of environmental and social impacts 2. careers an career ladders 3. discussion of laboratory activities, results, and related procedures

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module, develop or update your daily lesson plans, generate handouts, collect examples, select the media and materials necessary to support your instruction, and determine activities capable of supporting the module's content.

Identify, develop, and/or test material or product samples, equipment, and procedures that will be used to demonstrate or reinforce the understanding of identified separation material conversion processes and principles. Record these procedures and identify specific safety considerations for each.

Develop and/or acquire six-eight individuals (or group) separation laboratory activities capable of supporting and developing an understanding of separation processes, and the common principles used to describe and analyze the separation of industrial engineering materials.

These activities should use shearing, machining, and nontraditional methods of processing metallic, ceramic, polymer, and composite materials. Processes that utilize a variety of cutting elements and and material motions should be considered when selecting separation laboratory activities.

Obtain and/or prepare materials for selected laboratory activities.

Identify and give students reading assignments before scheduled lectures, discussions, and/or demonstration.

1 Introduce and discuss "Separating Industrial Materials." This presentation should set the stage for the module and introduce the common principles of separation processes. (This should be approximately 15-25 minutes in length.)

The common principles used to describe separation material conversion processes are as follows:

1. types of separation processes
    a. shearing
    b. machining
    c. nontraditional.
2. types of cutting elements
    a. single point
    b. multiple point
    c. other medium.

DAY **ACTIVITY**

3. Cutting element or material motions
   a. linear
   b. reciprocating
   c. rotary
4. coolants
5. material or cutting element support.

Emphasis should be placed on the principles of separation processes rather than the specific steps needed to make a single kind of cut or turning.

Potential separation processes for discussion include:

1. blanking
2. notching
3. nibbling
4. punching
5. squaring
6. machining with a band saw
7. machining with a circular saw
8. machining with portable power tools
9. machining with a radial arm saw
10. machining with a scroll saw
11. machining with a lathe
12. machining with a drill
13. machining with a mill
14. machining with a shaper
15. machining with a planer
16. machining with a jointer
17. machining with a router
18. abrading hand and machine
19. grinding
20. lapping
21. polishing
22. honing
23. EDM and ECM
24. torch cutting
25. laser beam cutting
26. slicing
27. chemical machining
28. hydro-cutting
29. abrasive jet.

Discuss separation laboratory activities which will be used during this module.

Demonstrate one or more of these activities to reinforce the concepts of material separation.

DAY **ACTIVITY**

2 Show a film that illustrates examples of industrial separation processes.

Draw students into a discussion of the film. Use the common principles of separation processes to help the students understand the processes in the film which they are unfamiliar with.

3 Review common principles of separation processes.

Reinforce the discussion by demonstrating selected separation processes (activities) that will be performed during this module.

As activities are being demonstrated, describe how each step in the procedure is a part of, or can be described, using the common principles of separation processes.

Typical activities might include:

1. the use of a hacksaw, grinder, file and abrasive to machine and surface-finish a forged screwdriver blade and handle
2. blanking a metallic part to be formed using flexible die forming
3. drilling holes for an assembly operation
4. machining and sanding a formed laminated wooden product
5. cutting engineering materials into parts or products
6. producing a small product utilizing machines that demonstrate a variety of machine and material motions
7. machining a hole using EDM
8. separating an extruded ceramic part or product
9. separating several different engineering materials into parts for later assembly into a product.

Students should take notes on laboratory activity procedures and safety considerations.

4 Assign separation laboratory activities and work with students as they begin their work.

Note: Recommend a minimum of six activities for a group of twenty students. Number of recommended activities is based on the assumption that students will work as individuals or in groups of two. Therefore, the possibility exists that all students will not perform the same activities. However, each student should complete a core of activities. Rotate students through activities.

DAY	ACTIVITY
	Observe and assist students working on separation activities.
	Rotate students through activities as needed.
5-6	Observe and assist students as they continue to work on separation activities.
7-8	Introduce, demonstrate, and discuss additional separation activities.
	Students should record procedures and safety practices introduced during demonstrations.
9-12	Observe and assist students as they continue to work on separation activities.
13	Present a discussion of separation processes and their common principles as applied to selected, identified, industrial separation processes.
	Review separation activities performed or discussed in class.
	Discuss impacts of separation processes and industries on individuals, society, and environment.

Suggested Textbooks

Kazanas, H. C., G. Baker, and Gregor, Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 184-253.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 131-193.

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MODULE: 7 : Conditioning Processes

LENGTH: 4 DAYS Manufacturing CLUSTER

Conditioning processes are classified as secondary material conversion processes which can change a material's physical and mechanical characteristics and/or properties. During the manufacture of a part or product conditioning, processes are primarily used to: improve the processing characteristics of a part or material, remove internal stresses developed during prior processing, and impart desired properties or characteristics. Therefore, the study of conditioning processes should involve discussion and activities supporting an investigation into the reasons for, and common principles and basic methods of, converting a material's internal or surface structure. These common principles are as follows:

1. characteristics or properties desired
    a. mechanical
    b. physical
    c. chemical
    d. thermal
    e. optical
    f. acoustical
    g. physicochemical
    h. processing
    i. environmental.
2. structure to be converted
    a. atomic (bonding)
    b. crystal
    c. molecular
    d. micro-macro.
3. conversion processes
    a. thermal
    b. mechanical
    c. chemical
    d. acoustical
    e. optical
    f. electrical.
4. characteristics or properties obtained
    a. mechanical
    b. physical
    c. chemical
    d. thermal
    e. optical
    f. acoustical
    g. physicochemical
    h. processing
    i. environmental.

The content for this module should be centered around these principles as they are applied to conditioning processes performed on a number of different engineering materials. The principles and their related subcomponents will, hopefully, help the learner to understand new and unfamiliar conditioning processes, and serve as a basis for transferring knowledge related to conditioning material conversion processes.

Care should be taken not to overemphasize a single type of material such as metallics or even a specific type such as steel. Nor should all conditioning processes performed be of the thermal variety.

Introducing students to a broad array of possibilities within each type of material conditioning process should be the goal of the module. Also, principal emphasis should be placed on the principles of conditioning processes as opposed to the specific skill needed to complete one or two selected products.

This module is organized to introduce students to the secondary processes of conditioning during the first stages of the module. Later in the module each student will complete several laboratory-centered conditioning processes utilizing several different materials. Because of the nature of conditioning processes, many of the laboratory activities will be performed on parts or products that were produced (cast, formed, separated, etc.) during earlier laboratory activities. These processes should reinforce the content and principles of conditioning processes. The number of conditioning activities completed will vary with time, student abilities, and other similar factors.

Finally, the student should enter into a review session where the principles of conditioning material conversion processes are reinforced and various conditioning processes are compared and contrasted.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe a conditioning material conversion process.
2. Identify and describe the four principle elements of a conditioning process.
3. Identify and describe a minimum of five basic types or forms (basic methods of conversion—for example, thermal, mechanical, magnetic, chemical, accoustical, optical, and electrical) or conditioning processes.
4. Identify and describe selected properties and/or characteristics commonly affecting conditioning material conversion processes.
5. Identify and describe the types of material structures converted during a conditioning process.
6. Identify and describe selected reasons for conditioning materials during manufacturing.
7. Identify and describe how selected conditioning processes alter a material's structure.
8. Describe the procedures used to convert identified industrial materials using selected conditioning processes.
9. Produce parts or products using selected material conversion conditioning processes.
10. Compare and contrast the procedures and output of selected conditioning processes.
11. Discuss the impacts of conditioning material conversion processes and industries on individuals, society, and environment.
12. Describe the input-process-output relationship for identified conditioning processes.
13. Be aware of the careers an career ladders for employees involved in conditioning processes.

DAY **ACTIVITY**

1 Introduction to and discussion of conditioning manufacturing processes.

1. discussion of conditioning processes and principles
2. demonstration and discussion of conditioning processes and principles

2 Review and discussion of conditioning principles and processes.

1. demonstration and discussion of conditioning processes and principles
2. assigning and conducting conditioning laboratory activities

3 Conducting conditioning laboratory activities.

Observation of and assisting students working on conditioning activities.

4 Review and discussion of conditioning principles and laboratory activities.

1. discussion of environmental and social impacts
2. careers and career ladders
3. discussion of laboratory activities, results, and related procedures

PRESENTING THE MODULE

DAY	ACTIVITY
0	Before you introduce this module, identify, develop, and/or test materials or products equipment, and procedures that will be used to demonstrate or reinforce the understanding of identified conditioning processes and common principles. Record these procedures and identify specific safety considerations for each. Develop and/or acquire six-ten individuals (or group) conditioning laboratory activities capable of supporting an developing an understanding of conditioning processes and the common principles used to describe and analyze the conditioning of industrial materials. These activities should use thermal, mechanical, magnetic, chemical, acoustical, optical, and/or electrical processes to condition metallic, ceramic, polymer, and composite materials. Obtain and/or prepare materials for selected laboratory activities.
1	Introduce and discuss "Conditioning Industrial Materials." This presentation should set the stage for the module and introduce the common principles of conditioning processes (this should be approximately 20-30 minutes in length). The common principles used to describe conditioning material conversion processes are as follows:

1. characteristics or properties desired
   a. mechanical
   b. physical
   c. chemical
   d. thermal
   e. optical
   f. acoustical
   g. physicochemical
   h. processing
   i. environmental.
2. structure to be converted
   a. atomic (bonding)
   b. crystal
   c. molecular
   d. micro-macro.
3. conversion processes
   a. thermal
   b. mechanical
   c. chemical
   d. acoustical
   e. optical
   f. electrical.

DAY **ACTIVITY**

4. characteristics or properties obtained
    a. mechanical
    b. physical
    c. chemical
    d. thermal
    e. optical
    f. acoustical
    g. physicochemical
    h. processing
    i. environmental.

Emphasis should be placed on the principles of conditioning processes rather than the specific steps required to harden steel.

Industrial processes to be discussed or used as examples might include:

1. seasoning lumber
2. hardening
3. tempering
4. annealing
5. normalizing
6. firing
7. hydration
8. polymerization
9. work hardening
10. surface hardening
11. heat treating glass.

Discuss conditioning laboratory activities which will be used during this module to reinforce content.

Potential laboratory activities include:

1. using water extended polyester to make a handle for a screwdriver
2. normalizing, annealing, hardening, and/or tempering the blade for the screwdriver
3. firing the ceramic parts and/or products produced during casting and molding activities
4. mixing and placing concrete
5. seasoning some lumber
6. using and studying the curing processes of adhesives
7. magnetizing a product or material.

DAY	ACTIVITY
	Demonstrate one of the identified laboratory conditioning processes emphasizing the common principles of a conditioning process during the demonstration.
2-3	Continue demonstrating conditioning processes to be used during this module.
	As activities are being demonstrated describe how each step in the procedure is a part of or can be described using the common principles of conditioning processes.
	Students should take notes on activity procedures and safety considerations.
	Assign conditioning activities and work with students as they complete their work and their Activity Analysis Sheets.
4	Discuss conditioning processes and their common principles as applied to selected, identified, industrial conditioning processes.
	Review conditioning activities performed or discussed in class.
	Discuss impacts of conditioning processes and industries on individuals, society, and the environment.

INSTRUCTIONAL MATERIALS

1. Teacher developed and/or commercially available transparencies/slides/charts, etc., describing conditioning manufacturing activities and processes.
2. Conditioning equipment and part or product examples capable of being used to demonstrate or describe conditioning material conversion processes; their characteristics, procedures, results, and/or by-products.
3. Handouts on conditioning material conversion processes that may not be addressed in student text.
4. Instructor daily lesson plans.
5. Conditioning laboratory activities.
6. Teacher designed conditioning material conversion laboratory activity analysis sheet which will cause the student to:

   a. identify and describe the industrial, social, and economic advantages and disadvantages of the identified process
   b. identify and describe the material being converted
   c. identify and describe the desired material characteristics or properties to be obtained through the use of the conditioning processes.
   d. identify and describe the materials, structure(s) to be converted
   e. identify and describe the conversion process(es) used to obtain the desired material characteristics or properties
   f. identify and describe the characteristics or properties obtained through use
   g. record obervations during the activity and about the finished part or product (reasons for the defects should be considered)

SPECIAL EQUIPMENT AND SUPPLIES

1. The following materials are not required, but will provide better learning opportunities for the students:

   a. ceramic kiln
   b. small electric or gas furnace for heat treating
   c. molds, mixing equipment, polymer materials for chemical conditioning (polymerization)
   d. forms, mixing equipment, cement, and aggregate for mix concrete
   e. small electric oven or other equipment for drying small pieces of wood.

2. Safety equipment necessary for observing demonstrations and performing laboratory activities

BIBLIOGRAPHY

Suggested Textbooks

Kazanas, H. C., G. Baker, and Gregor, Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 331-341.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 317-355.

MODULE: 8 : Assembling Processes

LENGTH: 7 DAYS Manufacturing CLUSTER

Assembly processes are classified as secondary material conversion processes which semi- or permanently join two or more materials or parts together. Almost every industrial and consumer product manufactured must be assembled from several parts and/or subassemblies. The study of these processes should involve discussion and activities supporting an investigation into the reasons for, and common techniques used, to join industrial materials and parts. The common techniques used to join materials or parts during assembly include:

1. mixing
2. joining
   a. adhesion
   b. cohesion
   c. mechanical
3. weaving
4. magnetic.

Other factors to be taken into consideration during the investigation of an assembly process, along with a study of the common techniques or processes or assembly are:

1. consideration of the characteristics and properties of the fastener or material being added
2. preparation of the base material or fastening agent for the assembly process
3. method of applying the fastener or material being added.

The content for this module should be centered around these techniques and factors as they are applied to assembly processes performed on a number of different engineering materials. The techniques and their related subcomponents will, hopefully, help the learner to understand new and unfamiliar assembly processes, and serve as a basis for transferring knowledge related to assembly processes. Care should be taken not to overemphasize a particular technique or the use of a particular material.

Introducing students to a broad array of assembly techniques should be the goal of the module. Also, principal emphasis should be placed on the techniques and other factors affecting the assembly processes as opposed to the specific skills needed to complete one or two selected products.

This module is organized to introduce students to the secondary processes of assembly during the first stages of the module. Later in the module each student should complete several laboratory-centered assembly processes utilizing several different materials. Because of the nature of assembly processes, many of the laboratory activities will be performed on parts or subassemblies that were manufactured (cast, formed, or separated) during earlier laboratory activities. These processes should reinforce the content and techniques of assembly processes. The number of activities completed will vary with time, student abilities, and other similar factors. Finally, the student should enter into a review session where the principles of assembly processes are reinforced and various assembly processes are compared and contrasted.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe the purposes of assembly material conversion processes.
2. Identify and describe the four basic techniques used to assemble parts and subassemblies.
3. Describe the importance of assembly processes in the manufacturing activities.
4. Identify and give a brief description of the basic methods used to join parts or subassemblies.
5. Identify and describe selected reasons for semi- or permanently assembling parts or subassemblies together.
6. Identify several industrial materials and describe a common industrial processes used to fasten it to itself or another similar and/or dissimilar material.
7. Produce parts or products using selected assembly processes.
8. Compare and contrast the procedures and outputs of selected assembly processes.
9. Discuss the impacts of assembly processes and industries on individuals, society, and environment.
10. Be aware of the careers and career ladders for employees involved in assembly processes.
11. Be able to analyze an identified assembly process using the common techniques and factors of an assembly process.

CALENDAR

DAY	ACTIVITY
1	Introduction to and discussion of assembling industrial materials. 1. discussion of assembling processes and techniques 2. show and discuss a film illustrating examples of industrial assembly processes
2	Review and discussion of assembling processes and techniques. 1. demonstration and discussion of assembly processes and techniques 2. assigning and conducting assembly laboratory activities
3-4	Conducting assembling laboratory activities. Observation of and assisting students working on assembling activities.
5	Review and discussion of assembling processes and techniques. 1. demonstration and discussion of assembly processes and techniques 2. assigning and conducting assembly laboratory activities
6-7	Conducting assembling laboratory activities. Observation of and assisting students working on assembling activities.

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module, develop or update your daily lesson plans, generate handouts, collect examples, select the media and materials necessary to support your instruction, and determine activities capable of supporting the module content.

Identify, develop, and/or test material or product samples, equipment, and procedures that will be used to demonstrate or reinforce the understanding of identified assembling processes. Record these procedures and identify specific safety considerations for each.

Develop and/or acquire six-eight individual (or group) assembling laboratory activities capable of supporting and developing an understanding of assembling processes, and the common principles used to describe and analyze the assembling of industrial materials.

These activities should use mixing, joining, weaving, and/or magnetic processes to convert metallic, ceramic, polymer, and composite materials.

Obtain and/or prepare materials for selected laboratory activities. On specified work days have appropriate laboratory activities set up before class is scheduled to begin.

Identify and give students reading assignments before schedules lectures, discussions, and/or demonstrations.

1 Introduce and discuss "Assembling Industrial Materials." This presentation should set the stage for the module and introduce the common techniques of assembly processes. (This should be approximately 20-30 minutes in length.)

The common techniques used to describe assembly processes are as follows:

1. mixing
2. joining
    a. adhesion
    b. cohesion
    c. mechanical
3. weaving
4. magnetic.

Emphasis should be placed on the techniques of assembly processes rather than the specific steps required to weld or braze steel.

DAY **ACTIVITY**

Industrial processes and materials to be discussed or used as examples might include:

1. threaded fasteners
2. screws
3. nails
4. staples
5. rivets
6. retainers
7. clips
8. closures
9. joints and seams
10. adhesive bonding
11. soldering
12. brazing
13. sealants
14. welding plastics
15. friction welding
16. hot tool
17. gas welding
18. resistance welding
19. arc welding
20. other welding processes
21. magnetic.

Show a film illustrating several different types of industrial assembly processes. Discuss the implications of the film with the students. During discussion use the common techniques and principles of assembly processes.

2 Discuss assembly laboratory activities which will be used during this module to reinforce content.

Potential laboratory activities include:

1. nailing, bolting, screwing, soldering, brazing, pop riveting, welding, gluing, joining, and/or interlacing parts or subassemblies together
2. using solvents, arc welding, or slip welding to demonstrate cohesion bonding of parts or subassemblies together.

As activities are being demonstrated describe how each step in the procedure is a part of or can be described using the common principles of assembly processes.

Students should record procedures and safety practices presented during demonstrations.

3-4 Assign assembly laboratory activities and analysis sheets as needed.

Begin laboratory activities.

Note: Recommend a minimum of six activities for a group of twenty students. Number of recommended activities is based on the assumption that students will work as individuals or in groups. Therefore, the possibility exists that all students will not perform the same activities. However, each student should complete an identified core of activities.

DAY	ACTIVITY
	Observe and assist students as they complete the assembly activities.
5	Introduce, demonstrate, and discuss additional individual and/or group assembly laboratory activities selected and developed for this module. Students should record procedures and safety practices introduced during demonstrations.
6-7	Observe and assist students as they complete their assembly activities. Note: Review of assembly process is integrated into the finishing module.

SPECIAL INSTRUCTIONAL MATERIALS

An assembly laboratory activity analysis sheet should be developed which will cause the student to:

a. identify and describe the industrial, social, and economic advantages and disadvantages of the identified process
b. identify and describe the materials(s) being converted
c. identify and describe fastening agent or material(s) being added
d. identify and describe the assembly techniques(s) used
e. identify and describe the preparation of the base material and/or fastening agent or material being added
f. identify and describe the method/s used to apply the fastening agent or material being added

SPECIAL EQUIPMENT AND SUPPLIES

1. The following materials are not required, but will provide better learning opportunities for the students;
    a. pop rivet gun and rivets
    b. plastic solvents
    c. spot welder
    d. ceramic materials and equipment
    e. soldering or brazing materials and equipment

Suggested Textbooks

Kazanas, H. C., G. Baker, and Gregor, Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 254-330.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 356-382.

MODULE: 9 : Finishing Processes

LENGTH: 5 DAYS Manufacturing CLUSTER

Finishing processes are classified as secondary material conversion processes which protect, decorate, and/or change the function of a material by coating or converting the material's surface. During the manufacture of a part or product, finishing processes are primarily used to protect and decorate the material. The study of finishing processes should, therefore, involve discussion and activities supporting an investigation into the reasons for the common principles and basic methods of converting a material's surface through the application of a conversion or coating finish. These common principles of finishing processes are as follows:

1. select finish
    a. coating
    b. conversion
2. prepare material for finishing
    a. mechanical
    b. chemical
3. apply finish
    a. spraying
    b. dipping
    c. plating
    d. rolling
    e. brushing
    f. pouring

The content for this module should be centered around these principles as they are applied to finishing processes performed on a number of different engineering materials. The principles and their related subcomponents will, hopefully, help the learner to understand new and unfamiliar finishing processes and serve as a basis for transferring knowledge related to finishing material conversion processes.

Care should be taken not to overemphasize a single type of finish such as organic coatings or even a specific type such as varnish, nor should all finishing processes performed be brushed finishes.

Introducing students to a broad array of possibilities within each type of material finishing process, should be the goal of the module. Also, principal emphasis should be placed on the principles of finishing processes as opposed to the specific skill needed to finish one or two selected products.

This module is organized to introduce students to the secondary processes of finishing during the first stages of the module. Later in the module, each student will complete several laboratory-centered finishing processes utilizing several different materials. Because of the nature of finishing processes, many of the laboratory activities will be performed on parts or products that were produced (cast, formed, separated, assembled, etc.) during earlier laboratory activities. These processes should reinforce the content and principles of finishing processes. The number of activities completed will vary with time, student abilities, and other similar factors. Finally, the student should enter into a review session where the principles of finishing material conversion processes are reinforced and various finishing processes are compared and contrasted.

OBJECTIVES

Upon completing this learning module, each student should be able to:

1. Define and describe the purposes of finishing material conversion processes.
2. Identify and describe the three principle elements of a finishing process.
3. Identify and describe the basic methods used to prepare the surface of a material for a finish.
4. Identify and give a brief description of the basic methods used to apply a finish.
5. Identify and describe selected reasons for finishing materials during manufacturing.
6. Identify and describe how selected finishing processes can alter a material's surface.
7. Produce parts or products using selected material conversion conditioning processes.
8. Compare and contrast the procedures and outputs of selected finishing processes.
9. Discuss the impacts of finishing material conversion processes and industries on individuals, society, and environment.
10. Describe the input-process-output relationship for identified finishing processes.
11. Be aware of the careers and career ladders for employees involved in finishing processes.

CALENDAR

DAY	ACTIVITY
1	Introduction to and discussion of finishing industrial materials. 1. discussion of finishing processes and techniques 2. show and discuss a film illustrating examples of industrial film processes
2	Review and discussion of finishing processes and techniques. Demonstration and discussion of finishing processes and techniques.
3-4	Assigning and conducting finishing laboratory activities.
5	Review and discussion of assembly and/or finishing techniques and/or principles and laboratory activities. 1. discussion of environmental and social impacts 2. careers and career ladders 3. discussion of laboratory activities, results, and related procedures

PRESENTING THE MODULE

DAY **ACTIVITY**

0 Before you introduce this module, develop or update your daily lesson plans, generate handouts, collect examples, select the media and materials necessary to support your instruction, and determine activities capable of supporting the module content.

Identify, develop, and/or test material or product samples, equipment, and procedures that will be used to demonstrate or reinforce the understanding of identified finishing processes and principles. Record these procedures and identify specific safety considerations for each.

Develop and/or acquire six-eight individual (or group) finishing laboratory activities capable of supporting and developing an understanding of finishing processes, and the common principles used to describe and analyze the finishing of industrial engineering materials.

These activities should use organic and inorganic materials and be applied by spraying, brushing, pouring, dipping, rolling, and/or plating metallic, ceramic, polymer, and/or composite materials.

Obtain and/or prepare materials for selected laboratory activities.

Identify and give student reading assignments before schedules lectures, discussions, and/or demonstrations.

1 Introduce and discuss "Finishing Industrial Materials." This presentation should set the stage for the module and introduce the common principles of finishing processes. (This should be approximately 20-30 minutes in length.)

The common principles used to describe finishing material conversion processes are as follows:

1. select finish
    a. coating
    b. conversion
2. prepare material for finishing
    a. mechanical
    b. chemical
3. apply finish
    a. spraying
    b. dipping
    c. plating
    d. rolling
    e. brushing
    f. pouring.

DAY **ACTIVITY**

Emphasis should be placed on the principles of finishing processes rather than the specific steps required to plate steel.

Industrial processes and materials to be discussed or used as examples might include:

1. surface cleaning processes (mechanical and chemical)
2. organic and inorganic finishes
3. brushing
4. spraying
5. dipping
6. roller coating
7. electroplating
8. powder coating
9. oxide coatings
10. metal spraying
11. vacuum metalizing
12. pouring
13. phosphate coating
14. porcelain coating
15. ceramic coating.

Show a film illustrating several different types of industrial finishing processes. Discuss the processes shown in the film with the students.

Use the common principles of finishing processes to describe and help the students understand unfamiliar processes in the film and/or processes not included in the assigned readings.

2 Discuss finishing laboratory activities which will be used during this module to reinforce content. Potential laboratory activities include:

1. glazing (spray, dip, pour, or brush) a ceramic product
2. spray, dip, or brush parts or products manufactured during casting, forming, separating, assembling, or conditioning activities
3. staining and top coating a polymer part or product
4. silkscreening a package, design, or symbol on some part or product
5. converting the surface of a metallic part or product.

As activities are being demonstrated describe how each step in the procedure is a part of, or can be described, using the common principles of finishing processes.

Students should observe, take notes, and record observations of all demonstrated laboratory activities, procedures, and safety considerations.

DAY	ACTIVITY
3-4	Assign finishing laboratory activities and analysis sheets as needed. Begin laboratory activities. Note: Recommend a minimum of six activities for a group of twenty students. Number of recommended activities is based on the assumption that students will work as individuals or in groups. Therefore, the possibility exists that all students will not perform the same activities. However, each student should complete an identified core of activities. Rotate students through activities. Observe and assist students as they work on their finishing activities.
5	Discuss finishing and assembly processes and their common principles as applied to identified industrial processes. Review finishing and assembly activities performed or discussed in class. Discuss impacts of finishing and assembly processes and industries on individuals, society, and environment.

SPECIAL INSTRUCTIONAL MATERIALS

A finishing material conversion laboratory activity analysis sheet should be developed which will cause the student to:

1. **identify and describe the industrial, social, and economic advantages and disadvantages of the identified process**

2. **identify and describe the material(s) being converted**

3. **identify and describe the type and reasons for selecting a particular finish**

4. identify and describe the method(s) used to prepare the material's surface for the identified finish

5. identify and describe the method of applying the identified finish

SPECIAL EQUIPMENT AND SUPPLIES

The following materials are not required, but will provide better learning opportunities for the students:

- a. ceramic glaze
- b. spray equipment
- c. kiln
- d. equipment for metallic surface conversion

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BIBLIOGRAPHY

Suggested Textbooks

Kazanas, H. C., G. Baker, and Gregor, Basic Manufacturing Processes, McGraw-Hill Book Co., New York, 1981, pp. 343-360.

Wright, R. Thomas, Processes of Manufacturing, Goodheart-Willcox Co., South Holland, IL, 1987, pp. 383-409.

MODULE: 10 : Evaluating and Analyzing Products or Materials

LENGTH: 4 DAYS Manufacturing CLUSTER

Evaluating and analyzing processed industrial materials is a culminating activity (module) designed to give the student the opportunity to apply the concepts, principles, and knowledge of industrial materials, and manufacturing processes developed during this course. As indicated by the title of the module, the proposed task is basically one of evaluation, analyzation, and the use of logic and problem-solving skills. The "task", given a product:

1. having a minimum of ten parts
2. containing at least two different industrial materials (at least one from two of the following: metallics, ceramics, natural polymers, synthetic polymers, and composites)
3. manufactured using a minimum of five different processes (at least one from four of the following: casting, forming, molding, separating, conditioning, assembling, and finishing)
4. the student should be familiar with
5. a handout describing the assignment.

The students working in small groups (maximum three students per group) will be able to analyze an assigned product (each group should have a different product) and its individual parts to determine the type of materials utilized and how the product and its individual parts were manufactured.

The assignment will consist of a report in three parts:

1. a visual representation of the product with all individual parts shown and labeled (photo, sketch, mechanical drawing, etc.)
2. a bill of materials listing the quantity, the material from which it is manufactured, and a reasonable name for each part
3. the body of the report wherein each identified part is analyzed, in the order listed on the bill of materials. Analysis will consist of the identification and listing of all manufacturing processes used to produce the part, and a one or two sentence description of each identified process.

A NOTE CONCERNING EVALUATION: It should be noted that in many cases it will be extremely difficult to identify the exact material or processes used to manufacture a given part. In many cases (following library research, visits or calls to the manufacturer, and/or other appropriate research techniques), the student's identification or guess of a particular material or process may be just as accurate as the instructor's. The question should be, is the decision logical and reasonable, because in many cases, there may be several different materials or processes that could, or may have been used, to manufacture a particular part.

OBJECTIVES

Upon completing the learning module, each student or group of students should be able to:

1. Identify or give name of all the parts of an assigned product.
2. Use a form of visual communications to illustrate an assigned product and its individual parts.
3. Identify the materials used to make each identified part of the assigned product.
4. Research and analyze an assigned product to determine the material conversion processes used to manufacture each of its parts.
5. Provide a one or two sentence description of the identified processes determined to have been used to manufacture the individual parts of an assigned product.

CALENDAR

DAY	ACTIVITY
1	Introduce and discuss "Evaluating and Analyzing Processed Industrial Materials" activity.
2-3	Observe and assist students working on assigned activity.
4	Discuss preliminary results of product analysis. 1. discuss problems of material and process identification. 2. discuss and finalize assignment format
5	Student product analysis presentations.

PRESENTING THE MODULE

DAY	ACTIVITY
0	Before you introduce this module, develop or update your daily lesson plans, generate handouts, collect examples, select the media and materials necessary to support your instruction, and determine products capable of supporting the module content. Identify, develop, and/or test examples, and procedures that will be used to support this activity. Record these procedures and identify specific safety considerations for each. Obtain and/or prepare products for identified laboratory activity. On specified work days have appropriated products set up or available before class is scheduled to begin.
1	Introduce and discuss "Evaluating and Analyzing Processed Industrial Materials" activity. Show and give examples of completed assignments, procedure and techniques that were used to complete or determine them. Form small groups (use technique appropriate to the group of students involved). Assign products and give due date for assignment.
2-3	Observe and assist students as they complete the activity. Students should: 1. establish management system to guide work 2. research and/or analyze product and parts 3. work on activity.
4	Discuss preliminary results of product analysis. Discuss the problem of materials and processes identification. Discuss and finalize assignment format for submission.
5	Have students submit and discuss assignments, methods, and procedures used, results and findings, alternatives to processes and materials identified.